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Distribution of Sound

WE are inclined to think that the branch of our art described variously and not very elegantly as sound amplification, sound reinforcement, public address—and, what always makes us wince, "the broadcast"—may fairly be described as the Cinderella of electronics. Even the nomenclature is highly unsatisfactory; "public address" is stilted in the extreme, and has been deprecated by the British Radio Equipment Manufacturers Association. The association, however, has not in our view suggested a very happy alternative; the preferred "sound reproduction" should, we think, be an omnibus term covering all possible methods of reproducing sound artficially, and applicable to every kind of apparatus used to that end. "Sound reinforcement," though rather a mouthful, is much better when properly used to connote a system designed to amplify sounds that are already to some extent audible by natural means. "Sound distribution" seems to us the best general term out of a rather bad lot to replace "public address," though it would probably be rather arbitrary to suggest the term should be restricted to systems in which the source of the original sound is barely, if at all, audible (or visible) to the listener.

It seems desirable that some distinction should be drawn between the two most widely used systems of sound amplification. In what most people prefer to call sound reinforcement, naturalness is the prime requirement; the audience should not be aware that the speech or other sound coming to their ears has been artificially reinforced. Fidelity is thus needed. In public address or sound distribution, on the other hand, intelligibility is the prime criterion; as often as not, the speaker is anonymous, and there is no illusion of naturalness to be preserved.

These thoughts are provoked by an article printed elsewhere in this issue which deals with an interesting and promising method of preserving naturalness in sound reinforcement systems. Incidentally, the article comes as a reminder that even in the matter of literature sound distribution is less well served than most other branches of electronics, and the information published on the subject is relatively small. The paucity of literature may perhaps to some extent be attributed to the fact that sound distribution is to a considerable extent an art rather than a science; it makes use of many basically well-known techniques, but applies them in a highly specialized way.

Most readers will agree with us in thinking that a large number of sound distribution installations reflect little credit on the electronic art. We should hasten to add here that the blame for this is not always attributable to those who made the apparatus and planned its installation. In many cases misuse and poor maintenance are responsible for the deterioration that is so often noticeable after an installation has been in use for some months. Some sound distribution equipment is installed on a rental and maintenance basis, rather than on outright sale; this seems to be a practice that might well be extended.

Sound distribution is often brought into disrepute by causes that have nothing to do with the technical considerations involved. The employment of untrained and quite unsuitable announcers is a case in point; this is hardly our business, but we cannot but deplore the fact that at at least one London main line terminus there is an announcer who does not know the accepted pronunciation of a number of stations served by his line. Manufacturers of equipment might do some useful propaganda in such cases by pointing out that even the best equipment cannot remedy faults in diction!

Propaganda in other directions seems to be called for. We believe the Association of Public Address Engineers has already stressed to its members the need for remedying the shortcomings found in some installations, and we feel this relatively young association can do much useful work towards establishing a higher average standard of quality. After all, this is a matter that concerns all of us; the general public comes more closely into contact with speech amplification than with any manifestation of electronics except broadcasting. To some extent they will judge the capabilities of all applications of electronics by what they hear.

RECENT DEVELOPMENTS IN

Speech Reinforcement Systems

Use of Controlled Time Delays to Preserve Realism

By P. H. PARKIN, B.Sc., A.M.I.E.E. and W. E. SCHOLES, B.Sc.

DURING the past thirty years the technical equipment for speech reinforcement systems has been extensively developed and it is now possible to produce microphones, amplifiers and loudspeakers with practically any required specification. The associated acoustical problems; i.e., the relation of the use of the equipment to the sound as heard by the listeners, has received comparatively little attention. Recent research on the audibility of speech by Haas and Meyer[1] in Germany, while concerned primarily with room acoustics, has a considerable bearing on speech reinforcement systems. In addition Beranek,[2] and Beranek, Radford and Wiesner[3] in America have been investigating the performance of such systems, and Doak and Bolt[4] have extended the original work of Haas. It is the purpose of this article to bring together the results of these investigations to see how they affect the design of speech systems. Experiments made by the authors which confirm these results will also be described.

Speech reinforcement systems (hereafter referred to simply as systems) should make speech intelligible without loss of realism or naturalness. In most cases it is comparatively easy to make the speech intelligible, but it is often difficult to do so without losing naturalness and without inducing a strain in the listener. This article is mainly concerned with this problem of the retention of naturalness, although the results also have some bearing on improved intelligibility.

Haas and Meyer Results

(a) *Echoes with Short Delay Times.*—Haas and Meyer were primarily concerned with room acoustics, in particular the effect of a single echo on the audibility of speech. "Echo" in this context is defined as a reproduction of the original or direct sound delayed behind the original sound and differing from it only in amplitude. (The word "echo" is used to describe the second sound even when the time delay and amplitude are too small for the ear to perceive it as a separate entity.) Although they used loudspeakers to produce both the original sound and the echo, this was done purely as a matter of technique; these loudspeakers were intended to imitate actual acoustical conditions. Their results are not strictly comparable with a speech reinforcement system used in a room with a finite reverberation time, but for the time being it will be assumed that the system is used under open-air conditions. This point will be dealt with more fully later.

The echo was delayed by using a loop of magnetic tape, and their first experiments were made under open-air conditions using two loudspeakers placed three metres in front of the observer, subtending an angle of 45 deg. Both loudspeakers were fed with speech at the same intensity. With no delay on the "echo" loudspeaker the sound appeared to come from a point mid-way between the loudspeakers; that is, from directly in front of the observer. Now if the echo loudspeaker was delayed by five milliseconds it was not heard at all by the observer although the loudness remained the same. That is to say all the sound appeared to be coming from the primary loudspeaker. This apparent direction of sound effect, which will be referred to as the Haas effect, was maintained for delays up to about 35 msec, but at about this time delay the echo loudspeaker began to be recognized as a secondary source although the sound source was still located at the primary loudspeaker. At delays of 50 msec and greater the second loudspeaker was heard as a distinct echo in the normal sense of the word, but the secondary loudspeaker was completely masked by the primary loudspeaker over the time delay range of 5 to 35 msec.

The next step was to determine quantitatively the extent of the masking. This was done by allowing the observer to reduce the intensity of the primary loudspeaker until both loudspeakers appeared to be heard at the same loudness. The average results from 15 observers have been plotted as the difference in intensities for equal loudness as a function of time delay (Fig. 1). Under these conditions the observers were conscious of the two loudspeakers as separate sources.

Only two further results with short time delays need concern us here. It was found that the Haas effect was independent of the position of the echo loudspeaker, and that with the two loudspeakers at the same intensity the increase in loudness was proportional to the increase in power; i.e., 3 db, as compared with a single loudspeaker.

At this stage we may illustrate the bearing of these

[1] "The Influence of a Single Echo on the Audibility of Speech." A dissertation by H. Haas for a doctor's degree, under the supervision of Prof. E. Meyer, University of Göttingen. Available from the Building Research Station as Library Communication 363. (Dec. 1949.)
[2] Beranek, L.L. *Proc. I.R.E.* Vol. 35, p.880, 1947.
[3] Beranek, L.L., Radford, W. H., and Wiesner, J. B. "Sound System Design for Reverberant Auditoriums," *Massachusetts Institute of Technology Quarterly Report*, p.5, Jan.-Mar., 1950.
[4] Doak, P. E. and Bolt, R. H., "A Tentative Criterion for the Short-Term Transient Response of Auditoriums," *Journal of the Acoustical Society of America*, Vol. 22, No. 4, p.507, 1950.

results on speech reinforcement systems by a simple example. If in a rectangular hall the human speaker using a microphone is at the centre of the platform, with two loudspeakers on either side of the platform, then most of the audience will hear one or other of the loudspeakers a few milliseconds before they hear the direct voice. Thus the sound will appear to them to be coming from one or other of the loudspeakers, which, particularly for those near the front, is obviously unnatural. On the other hand if a loudspeaker is placed, say, 20 feet above the human speaker all the audience will hear the direct voice first.

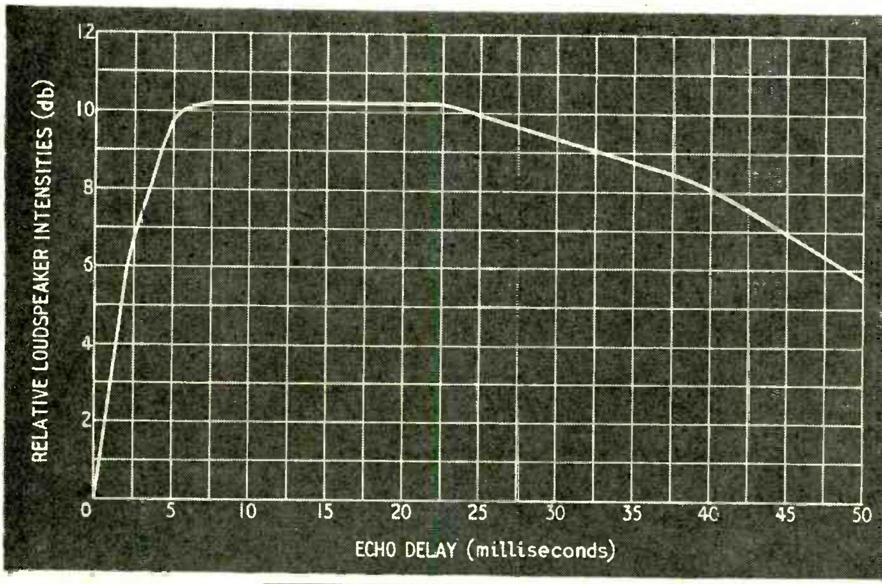
The sound will then appear to be coming from the human speaker (with an obvious gain in realism) unless the loudspeaker is received at an intensity of about 7 db greater than that of the direct voice. The figure of 7 db means that the echo is 3 db below the value for equal loudness; this ensures that the echo is not heard as a separate sound.

(b) *Echoes with Long Delay Times.*—Haas and Meyer continued their experiments with longer time delays; for technical reasons these further experiments were conducted in a medium-sized room with an average reverberation time of about 0.8 second, but the possible effects of the change from open-air conditions to reverberant conditions need not concern us here.

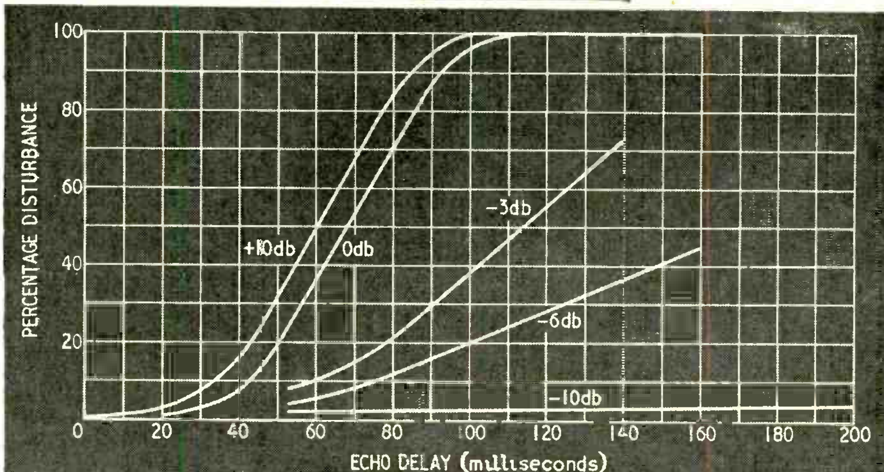
We have seen that when the echo time delay was about 50 msec the observer heard the second loudspeaker as a discrete echo. At this stage the echo had begun to interfere with the naturalness of the speech and it was the object of these further experiments to determine the amount of this interference as the amplitude and time delay of the echo were varied. It was found that the usual type of intelligibility test was, for various reasons, not suitable for this purpose. Instead the observers were asked to say when they were "disturbed" by the echo; i.e., when listening became unpleasantly strained, even if the speech was still fully intelligible.

About 100 observers were used for these tests and the results for a speed of speech of 5.3 syllables per second are shown in Fig. 2 where the percentage of observers who were disturbed by the echo is plotted against echo delay time for various echo amplitudes relative to the first sound amplitude. It is seen, for example, that when the echo had the same intensity as the first sound, 20 per cent disturbance was found for a delay time of 50 msec. If the echo intensity was reduced by 3 db then for 20 per cent disturbance the delay time could be as long as 80 msec.

Before going on to discuss the practical application of these results it will be easier to consider them plotted in a different form. Doak and Bolt[4] have derived from Haas' work, supplemented by their own studies, a tentative criterion for the transient acoustic response of rooms. They have plotted contours of constant percentage disturbance as a function of echo intensity—relative to the direct sound



Above : Fig. 1. Relative intensities for equal loudness as a function of the echo delay time.



Right : Fig. 2. "Disturbance" contours for various echo amplitudes as a function of the time delay.

intensity—and echo delay time (Fig. 3). (They have extrapolated Haas' results and also modified them slightly to allow for the difference between the average German speech rate of 5.3 syllables per second and the English rate of 4.5.) Thus, for example, an echo of the same intensity as the first sound will cause about 15 per cent disturbance if delayed by 50 msec and about 70 per cent disturbance if delayed by 100 msec.

Now this replotting of Haas' results is perfectly straightforward for single echoes; in room acoustics, however, the original or direct sound is not followed by a single echo but by a multiplicity of reflections. Doak and Bolt go further than Haas and suggest that this disturbance plot will also apply, at least in general shape, for room acoustics. This suggestion they base on the previous work of Mason and Moir,[5] of Somerville,[6] and on their own investigations. It is also borne out by a test made by the authors in a theatre where at some positions in the circle it was difficult to hear the speech, while in the balcony, farther from the stage, hearing was perfect. A pulse of tone at 800 c/s lasting for 15 msec was fed to a loudspeaker on the stage. Envelope tracings of the resultant sound fields received by a microphone and displayed on a cathode-ray tube are shown plotted against the Doak and Bolt criterion on Fig. 4. At the good position the response kept, in general, at about the 10 per cent disturbance contour, while at the bad position the response was up to the 50 per cent disturbance contour. Articulation tests at the two positions gave 96 per cent for the good position and 78 per cent for the bad position.

The original Haas work is now being continued in Germany with a series of echoes and when this work is complete it will be possible to decide accurately on the disturbance plot. The present evidence tends to show that the Doak and Bolt criterion as it stands is rather too stringent; in the good position in the theatre referred to above a team of listeners all reported perfect hearing and the disturbance was certainly not as high as 10 per cent.

To sum up, the behaviour of a speech reinforcement system consisting of one loudspeaker only and used in the open air can be assessed accurately by the Haas results alone. With multiple loudspeakers in the open air the directional effect can be determined exactly, but the disturbance effects may not be assessed so accurately because of the multiplicity of the sounds reaching the listeners. The same remarks apply to loudspeakers in rooms, but it appears that the Haas results as replotted by Doak and Bolt will give at least a qualitative guide to the disturbance.

Application of Haas Effect

We can now go on to discuss the practical application of these results to speech reinforcement systems There are two main criteria to bear in mind: (a) the apparent direction of speech depends on the relative time delay (Fig. 1), and (b) the successive sounds received by the listener should be of such relative amplitudes as to cause minimum disturbance (Fig. 3).

A simple system involving one loudspeaker working at a comparatively high sound level has already been mentioned. From Fig. 1 it is seen that the loudspeaker sound should reach the listener between about 5 and 35 msec later than the direct unamplified sound and should not exceed it in amplitude by more than about 7 db. If these conditions are fulfilled all the sound will appear to be coming from the human speaker. In this connection it is useful to remember that an increase in amplitude of 8 db is needed to double the sensation of loudness.[7]

For simple high-level systems the required time delay can often be obtained by placing the loudspeaker farther from the audience than the human speaker. For distributed systems employing a number of loudspeakers working at a comparatively low level, some form of electrical delay is required. It is often the case that unamplified speech can be easily heard over most of a hall while in some areas, particularly beneath deep balconies, hearing is difficult. If loudspeakers are used without a time delay to serve such an area, for example by putting some loudspeakers on the rear wall, the effect is obviously unnatural and disturbing. If, however, an appropriate time delay is introduced into the circuit, equivalent to the time taken for the direct sound to reach this area plus 5 to 35 msec, then the total loudness of the sound in this area can be almost doubled without the listeners being aware that most of the sound is coming from behind them. It might

[5] Mason, C. A. and Moir, J. "Acoustics of Cinema Auditoria" *J.I.E.E.*, Vol. 88, III, No. 3, p.175, 1941.
[6] Somerville, T., *B.B.C. Quarterly*, Vol. IV, I, 1949.
[7] Beranek, L. L., "Acoustical Measurements." Published by John Wiley, New York, 1949, and Chapman and Hall, pp.524-5.

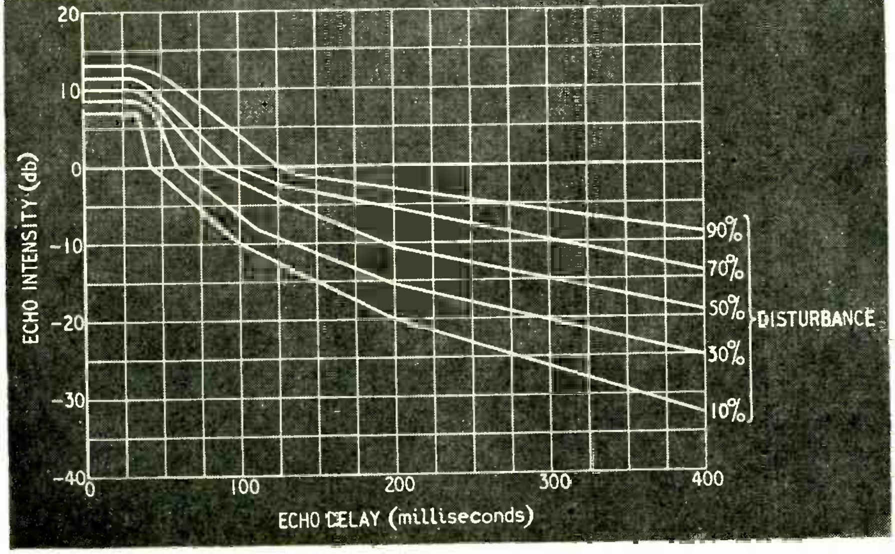


Fig. 3. Doak and Bolt criterion for the transient acoustic response of rooms.

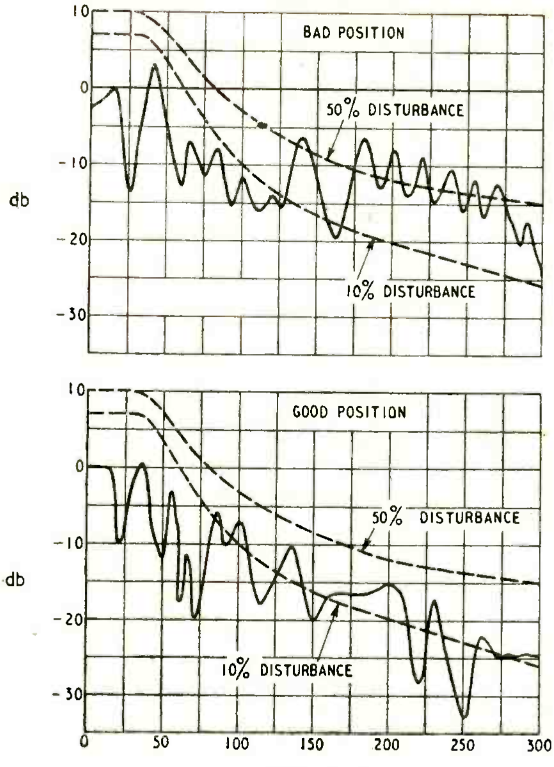


Fig. 4. Experimental plots of sound intensity from 15 msec, 800-c/s pulse at good and bad positions in a theatre. Doak and Bolt curves superimposed for comparison.

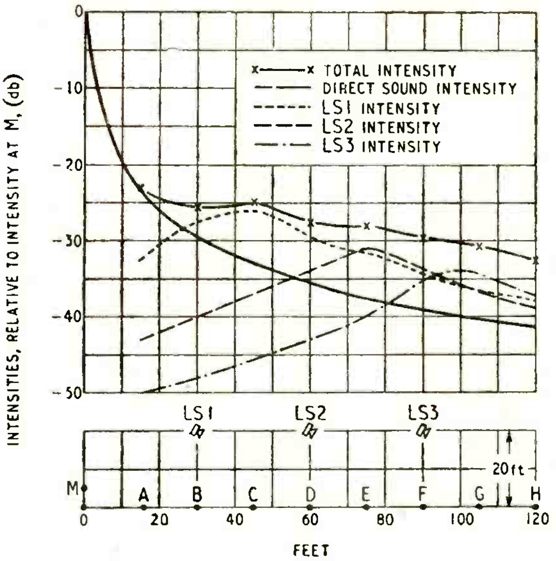


Fig. 5. Relative sound intensities in a typical sound reinforcement system.

be mentioned that such time delays have often been tried before to compensate for path differences, with varying success. The new and important result of the Haas effect is the *addition* of the 5 to 35 msec to ensure that the direct sound is heard first.

We will now consider the design of a low-level system. Suppose we have an auditorium 120 feet long with a longitudinal section as shown in Fig. 5. The plan need not concern us as far as the system design is concerned. The microphone and human speaker are at M, five feet above the heads of the audience, and three sets of loudspeakers are to be used, sets (1), (2) and (3), 20 feet above the heads of the audience. Typical listener positions are at A to H. The first step is to arrange for the correct time sequence so that to all listeners the sounds appear to be coming from the platform. It is a matter of simple arithmetic using the velocity of sound to decide that loudspeaker (1) should be delayed by 30 msec; loudspeaker (2) by 55 msec; and loudspeaker (3) by 80 msec. The time sequence of the sounds, to the nearest 5 msec, arriving at each listener position will then be as shown in Table I where the arrival of the direct sound from the human speaker is taken as 0 msec for each position.

The next step is to consider the relative amplifications that are desirable for each loudspeaker channel so that, maintaining adequate loudness, the separate speech sounds do not rise above, say, the 10 per cent contour on the Doak and Bolt criterion. It is obvious from Table I that the main danger is at the front seats where the sounds from the rear loudspeakers are a long time behind the direct sound. It would be an obvious advantage if the loudspeakers were directional; they would then have a smaller effect on the listeners between them and the platform. If the whole audio-frequency range is to be covered it is not easy to make loudspeakers uniformly directional. However, Beranek, Radford and Wiesner[3] have found that reinforced speech is not only more intelligible but also more natural if the frequency range is restricted as follows: flat between 300 and 4,000 c/s, 6 db down at 200 and 6,000 c/s, and falling off as rapidly as possible below and above this frequency range. If we restrict our system to this frequency range the loudspeakers can be quite directional, and as a conservative estimate we will assume that, as far as the polar diagram is concerned, for listeners under the loudspeakers the response will be 3 db down, and for listeners between the loudspeaker and the stage the response will be 6 db down. The human speaker will, for convenience, be assumed to be one foot from the microphone, and the gain of each loudspeaker channel will be defined as the intensity one foot in front of a loudspeaker referred to the intensity at the microphone. Now the direct sound intensity from the human speaker will, of course, fall

TABLE I
Sequence of Arrival of Sounds

Position	Delay behind direct sound (msec)		
	Loudspeaker (1)	Loudspeaker (2)	Loudspeaker (3)
A	40	85	135
B	20	60	110
C	10	35	85
D	10	20	60
E	5	10	35
F	5	5	15
G	5	5	10
H	5	5	5

off as the square of the distance (Fig. 5). Thus we know the intensity of the direct sound at each position and from Table I and Fig. 3 we can calculate the permissible gain of each loudspeaker channel so that the disturbance does not exceed 10 per cent.

A typical calculation would be as follows: At position C, loudspeaker (1) is 10 msec behind the direct sound (Table I). From Fig. 3 it is seen that the sound intensity at C from loudspeaker (1) may be 7 db greater than the intensity of the direct sound without destroying the illusion that all the sound is coming from the stage. The intensity of the direct sound at C, relative to the intensity at the microphone is −33 db. Thus the intensity at C from loudspeaker (1) may be −26 db. This is equivalent to an intensity of +2 db at a distance of one foot from loudspeaker (1) as the distance from the loudspeaker to C is 25 feet. By our previous definition the gain may thus be +2 db. Similar calculations for loudspeakers (2) and (3) give permissible gains of −3 db and −6 db respectively. The intensities at the other listener positions from the three loudspeakers can be calculated in a similar manner, and allowing for the directionality of the loudspeakers (Fig. 5). At positions C, E and G, the disturbance due to the loudspeakers (1), (2) and (3) respectively is 10 per cent. At all the other positions the sounds from the three loudspeakers come below the 10 per cent contour. It is known from Haas' work that it is permissible to add the intensities to obtain the total loudness. The total intensity is found to drop from −23 db at A to −33 db at H, a fall of 10 db equivalent to the loudness at H being rather less than half the loudness at A.

This theoretical system has been designed to comply strictly with the Haas results. In a practical system it should be remembered that there is the visual influence on the listeners; i.e., they see the human speaker and expect the sound to come from him. Thus it is probable that appreciable deviations from the theoretical ideal may be permissible.

Finsbury Park Open-air Theatre

To check this type of calculation an experimental speech reinforcement system was set up at the London County Council open-air theatre at Finsbury Park. An open-air theatre was chosen for the experiments to be free from the complications of room acoustics. In the event it was found that the noise level (in common with most open-air theatres) was too high for the disturbance effects to be assessed. The system had to be run at a higher level of amplification than was desirable, in fact only just below the feed-back level, and this caused a rather poor quality of reproduction which was in no way the fault of the equipment. However, the directional effect—the main purpose of the experiment—could still be investigated. On three nights of one week during a production of a Shakespeare play a low-level system similar to the theoretical system described above was used. Eight to ten observers were distributed about the theatre, a different team on each night. For the first part of the first act the delay system was used, for the middle part of the first act the same system, but without the delay, was used, and for the last part the delay system was again used. The observers knew that the system was changed at these intervals, but none of them knew which system was which. Not more than 25 per cent of the observers knew that the experiments were with a time delay system. With the undelayed system 10 out of the 28 observers said that the sound was coming from the stage, while the remaining 18 said it was coming from the loudspeakers; this result was roughly proportional to the expected answer, as some observers heard the direct sound first even with the undelayed system, and also because of the visual influence on them. With the delayed system all the 28 observers stated that the sound appeared to be coming from the stage.

Although the background noise was too great for the disturbance effect to be measured it was noticeable that, when the delays were switched out, the general audience in the parts of the theatre where the loudspeaker sounds were arriving before the direct sound soon became restless, but settled down again when the delays were restored.

On a fourth evening a time-delayed high-level system was tried, and these results will be considered in greater detail. Only one side of the theatre need be considered as the arrangement was symmetrical (Fig. 6). The loudspeaker was 25 feet above the ground and the nine observer positions are shown on the figure. With no delay on the loudspeaker the results were as shown in Table II. (The relative amplitudes of the direct sound and the loudspeaker sound were measured under conditions corresponding to the human speaker being an average distance of three feet from a microphone.)

TABLE II

High-level System (Undelayed)

Position	First sound	Time interval (msec)	Second sound	Amplitude of second sound relative to first (db)	Apparent source of sound
1	Loudspeaker	10	Direct	−2	Loudspeaker
2	Loudspeaker	25	Direct	−7	Loudspeaker
3	Loudspeaker	15	Direct	−4	Stage
4	Loudspeaker	35	Direct	−8	Loudspeaker
5	Loudspeaker	5	Direct	−2	Stage
6	Loudspeaker	25	Direct	−4	Loudspeaker
7	Loudspeaker	45	Direct	−5	Loudspeaker
8	Loudspeaker	25	Direct	−4	Loudspeaker
9	Loudspeaker	15	Direct	−3	Loudspeaker

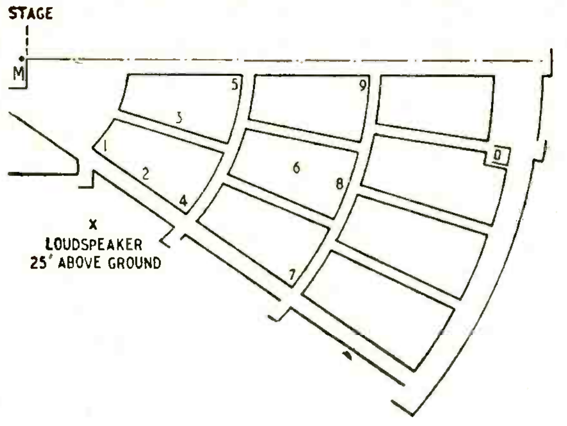


Fig. 6. Sketch plan of Finsbury Park Open-air Theatre.

At all positions the loudspeaker sound was the first to arrive. Seven of the nine observers stated that the sound appeared to be coming from the loudspeakers. The other two listeners, 3 and 5, said that the stage was the apparent source; according to the Haas results these were "wrong" answers, but it must be remembered that there is also the visual influence on the listeners. In these two cases apparently the visual influence overcame the aural influence.

With a 25 msec delay on the loudspeaker, the results were as given in Table III.

Seven of the nine observers now stated that the sound was coming from the stage. Observers 1, 3, 5 and 9 gave answers corresponding simply to the Haas effect: the direct sound reached them first and the loudspeaker was not apparent as a source, although its amplitude was from 2 to 4 db greater than the direct sound. For observer 2 the direct sound and the loudspeaker sound reached him at the same time, although the loudspeaker sound was 7 db greater than the direct sound the visual influence made the stage the apparent source. For observer 4 the loudspeaker sound reached him first by 10 msec, and again the visual influence overcame the aural influence. It is interesting to note that with the undelayed system the loudspeaker sound reached this observer 35 msec before the direct sound. The reduction of this delay to 10 msec caused the apparent source to change from loudspeaker to stage. Observers 6 and 8 heard the direct sound and the loudspeaker sound at the same time, and they were unable to decide where the sound was coming from.

The observers were also asked which system was more natural and which was more intelligible. Eight out of the nine observers said that the delayed system was more natural; the ninth observer noticed no difference. Eight said that the delayed system was more intelligible; the ninth said the undelayed system was more intelligible.

It would probably have been better to have introduced a loudspeaker delay of 40 msec instead of 25 msec. The received sounds would still have been within the 10-per cent Doak and Bolt criterion and the two undecided observers would almost certainly have decided on the stage as the apparent source.

Intelligibility.—The foregoing discussions have been concerned with realism, it being assumed that the intelligibility of the speech reinforcement systems was good. In some cases, particularly in very reverberant auditoria, intelligibility is the prime problem. The Haas and Doak experiments were not concerned with intelligibility, but it seems likely that if a system is arranged with time delays so that the received sounds from the system agree with the Doak and Bolt criterion, then the intelligibility will be improved.

Conclusions

(i) With a high-level system a better sense of realism is obtained by placing the loudspeaker so that its sound reaches the listener between 5 and 35 msec later than the direct sound from the human speaker. The loudspeaker sound can then be up to 7 db greater than the direct sound without the listeners being aware of the loudspeaker as a source of sound. Alternatively, a time delay can be introduced into the circuit to produce the same effect.

(ii) With a low-level system realism can be maintained by introducing successive time delays for each loudspeaker channel corresponding to the time taken for the direct sound to reach the listeners, plus 5 to 35 msec.

(iii) At bad hearing positions in auditoria local reinforcement using the appropriate time delay can be introduced up to 7 db greater than the direct sound without the listener being aware of the reinforcement.

(iv) In reverberant auditoria the intelligibility will

TABLE III

High-level System Delayed 25 msec

Position	First sound	Time interval (msec)	Second sound	Amplitude of second sound relative to first (db)	Apparent source of sound
1	Direct	15	Loudspeaker	+2	Stage
2	Direct	0	Loudspeaker	+7	Stage
3	Direct	10	Loudspeaker	+4	Stage
4	Loudspeaker	10	Direct	−8	Stage
5	Direct	20	Loudspeaker	+2	Stage
6	Direct	0	Loudspeaker	+4	Undecided
7	Loudspeaker	20	Direct	−5	Stage
8	Direct	0	Loudspeaker	+4	Undecided
9	Direct	10	Loudspeaker	+3	Stage

probably be improved by arranging for the loudspeaker sounds to be received in the proper sequence.

Acknowledgments.—The work described here is part of the research programme of the Building Research Board of the Department of Scientific and Industrial Research. In connection with the experiments in the Finsbury Park Open-air Theatre thanks are due to the Chief Engineer and the Second Officer of the Parks Division of the London County Council for experimental facilities given; Standard Telephones and Cables for the loan of the speech reinforcement system; and Electric and Musical Industries for the loan of the magnetic-tape recording equipment used for the time delay circuits.

Multi-Range Ohmmeter

Electronic Instrument with Automatic Range

By **I. B. DAVIDSON**, B.Sc., A.M.I.E.E.

THE need for a rapid and direct method of measuring resistance has led to the incorporation of an " ohmmeter " in most of the multi-range moving coil instruments now available for the servicing of electrical and electronic equipment. This type of ohmmeter is essentially a device for comparing the value of an unknown resistance with the internal resistance of the measuring instrument. Usually the basic circuit is that of Fig. 1(*a*) ; with this arrangement, short-circuiting of the terminals produces full scale deflection (f.s.d.) of the movement and this is the zero of the resistance scale. Introduction of resistance between the terminals causes a decrease in deflection and the resistance scale reads from right to left, unless the instrument is used only as an ohmmeter in which case it may be inverted.

An alternative arrangement is that of Fig. 1(*b*). In this case the indicating instrument is in effect a voltmeter and the unknown resistance is connected in parallel with it. The instrument reads zero when the terminals are short-circuited and gives f.s.d. on open circuit, so that the resistance scale reads from left to right. This ohmmeter is a little less convenient than that of Fig. 1(*a*) because the battery circuit must be completed, as a separate operation before use, and must be disconnected after use to avoid continuous discharge.

The deflection from zero on the resistance scale of either type for values of internal resistance R_0 ohms and external resistance r ohms is $\frac{r}{r + R_0} \times$ f.s.d. (R_0 is the effective internal resistance of the ohmmeter and is actually comprised of the fixed resistance R_a, the resistance of the meter and the internal resistance of the battery.) The resistance scale is, therefore, not uniformly divided.

Both these ohmmeters give half-scale deflection when the external resistance is equal to the effective internal resistance. Several ranges are provided by changing the value of R_0 in, say, decade steps. At the same time it is necessary to vary the meter sensitivity or the battery voltage in order that the instrument is fully deflected with the appropriate conditions, and in consequence change of range usually entails adjustment of the circuit resistance to give exactly full scale deflection on the meter.

With an ohmmeter arranged as Fig. 1(*a*) the lower limit of total internal resistance is mostly set by the maximum current which can be tolerated in the resistance to be measured. It is seldom desirable that this should exceed 150 mA, or that it should even reach this value, so that with a 1.5-volt cell, R_0 will not be less than 10 ohms. The upper limit is determined by the sensitivity of the milliammeter and by the acceptable battery voltage. Thus with a meter giving a f.s.d. for 1 mA and a 50-volt battery R_0 is 50,000 ohms. If the useful limit of the scale, before it becomes excessively cramped, is arbitrarily taken as 80 per cent of f.s.d., the highest indicated value of resistance is 200,000 ohms. Assuming that the smallest scale division is one per cent of f.s.d., the lowest value, using an appropriate battery voltage, is 0.2 ohm. Comparable considerations apply to an ohmmeter arranged as Fig. 1(*b*). Actually the scale division is initially uniform and at mid-scale is logarithmic ; towards full scale it becomes very cramped. It can, however, be seen from Fig. 2 that between 20 per cent and 80 per cent of f.s.d. there is an approximation to a logarithmic law.

The range of resistance values commonly encountered in electrical and electronic apparatus may be taken as from 1 ohm to 10 megohms. Multi-range moving coil instruments with a 1-mA movement mostly cover 1 ohm to 1 megohm using an internal battery and three ranges, but values greater than 200,000 ohms have to be indicated by extending the scale markings far into the cramped region. Such an arrangement, whilst useful, falls short of the ideal. The higher values of resistance, from 100,000 ohms to 10 megohms, have frequently to be measured, and even with the advantage of an almost logarithmic scale, it is not unreasonable to require at least six ohmmeter ranges to cover all the values between the limits stated. But since the whole range of values may be spanned in the course of a few consecutive measurements, range changing by switch, or even by the much more convenient push button, becomes at best an irritation. This is especially the case if readjustment of zero is required after switching. If, however, sacrifice of simplicity and the limitation imposed by mains operation can be accepted, as in a bench instrument, an ohmmeter employing a valve voltmeter may be constructed which offers the advantages of wide range and of automatic range selection, so that any value of resistance is indicated on the logarithmic portion of the scale.

Principle of the Valve Ohmmeter

The valve ohmmeter, which is now a frequent addition to multi-range valve voltmeters, usually has a basic circuit of the type shown in Fig. 1(*c*), and is identical with the arrangement of Fig. 1(*b*) except that V is now a valve voltmeter and has a very high resistance. The twin triode, together with R_1, R_2 and the milliammeter, form a bridge-type d.c. voltmeter. With the terminals short-circuited, R_1 and R_2 are adjusted so that balance is obtained and the milliammeter reads zero; this is the zero of the resistance scale. When the short circuit is removed, the grid of one half of the valve is biased by the cell and the circuit is so adjusted that the milliammeter now has full scale deflection. Connection of a resistance between the terminals reduces the p.d. between grid and cathode and produces a deflection of $\frac{r}{r + R_0} \times$ f.s.d. provided that r is small compared with the input resistance of the valve. The range of such an ohmmeter is altered by changing the value of R_a only; no alteration in battery voltage is required because of the very high voltmeter resistance and for the same reason it is unnecessary to disconnect the battery when the ohmmeter is not in use. Moreover the zero setting does not require adjustment when the range is changed. With these properties, and by means of a relay connected in series with the milliammeter, switching operations may be initiated so that the appropriate ohmmeter range is automatically selected upon connection of the unknown resistance.

Design of the Meter

The design of the valve voltmeter for such an ohmmeter is influenced by the sensitivity of the milliammeter and of the relay. An instrument giving f.s.d. for 100 μA together with a relay operating on some 2 milliwatts enables the construction of a very stable voltmeter with a high degree of linearity, but with the drawbacks of some frailty and rather high cost. As an alternative, a meter giving f.s.d. for 1 mA and a standard P.O. Type 3,000 relay with valve amplifier, offer the advantages of increased robustness and reliability with some sacrifice of linearity. In the type of work for which an ohmmeter is most useful, robustness and reliability are desirable features and for this reason the ohmmeter to be described is in the second category.

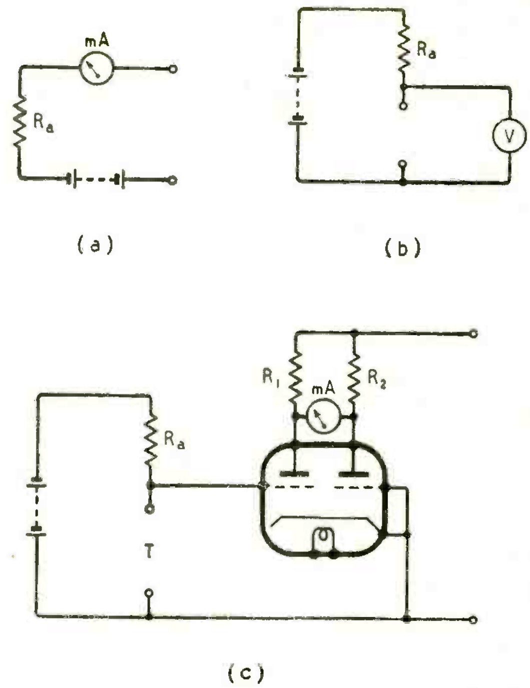


Fig. 1. Basic circuits of three types of ohmmeter:—(a) series-connected with moving-coil voltmeter, (b) alternative parallel connection, (c) parallel connection with valve-voltmeter.

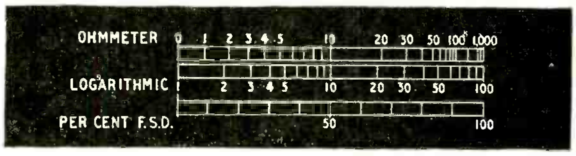


Fig. 2. Comparison of the scale of an ohmmeter with a logarithmically divided scale.

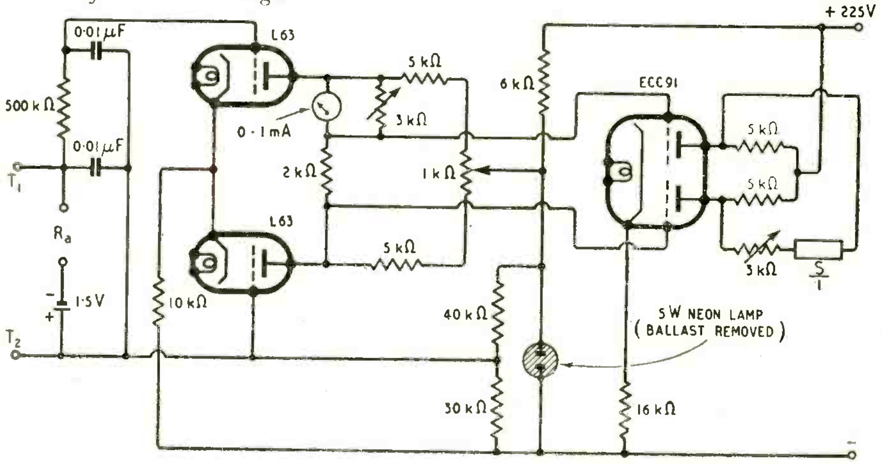


Fig. 3. Circuit of valve-ohmmeter and of balanced d.c. amplifier controlling operation of range-selection relays.

The voltmeter (Fig. 3) employs two medium impedance 6.3-volt triodes (or an equivalent twin triode) with a fairly high value common cathode resistor 10kΩ. The voltage across this is offset by means of the potential divider 40kΩ-30kΩ, and with the ohmmeter terminals short-circuited the grid of the top L63 is approximately 0.6 volt negative with respect to cathode. The h.t. supply is partially stabilized by a 5-watt neon lamp. It is important that the grid current of the top L63 should be very small and preferably less than 10 milli-microamperes; if the grid current is appreciable the deflection alters when the ohmmeter is switched to the "megohm" range. For this reason the valve heaters are operated at 6 volts and the anode-to-cathode voltage is 45/50 volts. The anode current of each valve is some 3.5 mA.

The input filter 0.01μF–500kΩ–0.01μF is used to minimise the effect of stray 50-cycle voltage when handling the leads, and these condensers have mica dielectric to ensure high insulation resistance. A cell is employed to provide the standing bias for the ohmmeter because the provision of 1.5 volts from the power pack, with a sufficiently low source resistance for the lowest range, involves the use of an inconveniently large smoothed and stabilized current. The cell has the disadvantage of uncertain and variable internal resistance, and means are provided for checking and correcting for this on the lowest range. Zero adjustment is effected by variation of the 1-kΩ and full-scale adjustment is obtained by the variable meter-shunt 3kΩ. The resistor 500kΩ and the two highest value sections of R_a are of the high stability carbon type; all other resistors in the voltmeter circuit are wire-wound.

The relay S which initiates range switching is operated by a balanced amplifier fed from the 2-kΩ. The amplifier employs a twin triode and delivers some 18 milliwatts to a Type 3,000 relay when the p.d. across the 2-kΩ is 2 volts as at f.s.d. The relay, which has a single pair of "make" contacts, is operated with a residual gap of approximately 20 "mils" and with slightly less than normal travel. It has a 3,000-ohm coil and operates with a current of 2 mA. The operating point, relative to ohmmeter deflection, is adjusted by a variable resistor 3kΩ and is normally set so that the relay contacts close when the deflection is 80 per cent of f.s.d. The operate/release ratio is of the order of 2 : 1.

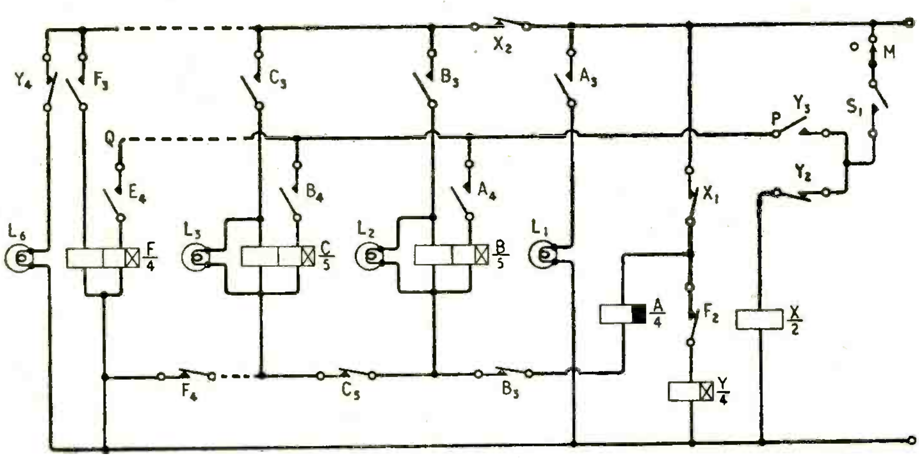
There are several ways in which the selection of the appropriate range can be effected. The method chosen, largely on grounds of simplicity and low power consumption, employs a bank of Type 3,000 relays operating in sequence and in one direction, in a closed chain (Fig 4). One relay is required for each ohmmeter range, together with two additional relays of the same type. All operate from a 12-V d.c. supply. The instrument described has six ranges, with values of R_0 from 10 ohms to 1 megohm, so that, with the initiating relay S, there are in all nine relays. Relays A to F select the value of R_a. Relay A has a copper slug at the heel end to delay release. Relays B to F have slugs at the armature end to delay operation and release and have two windings each. Y has a slug at the armature end and a single winding; X has no slug and a single winding. All relays except S have two make and three break contacts, though not all are in use.

Operation

(i) *Highest range.*—When switched on, and assuming that zero and f.s.d. have been correctly set, the ohmmeter is fully deflected with the terminals open-circuited. S and X are operated and all other relays are released. Because contact Y_1 is open, R_a is 1 megohm and the ohmmeter is, therefore, initially on the highest range.

(ii) *Other ranges.*—If now a resistance of, say, 20,000 ohms is connected, S releases, followed by X. Relays A and Y are energised through contact X_1, A operates and by opening A_1 adds 10 ohms to R_a. It is followed by Y and the closing of Y_1 short-circuits the 1-megohm resistor, so that the ohmmeter is switched to its lowest range. At the same time Y_2 and Y_3 transfer the contact S_1 from control of the relay X to control of the line PQ.

At this stage the function of contacts A_2, B_2, C_2 and D_2 will be ignored and they will be assumed to remain closed; their purpose is described later.



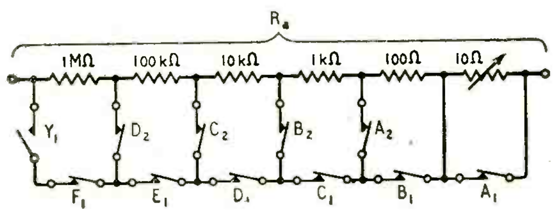


Fig. 4. Arrangement of the chain of range-selecting relays. Relays D and E are not shown in the upper drawing as they are merely a repetition of relays B and C.

Since the ohmmeter is on its lowest range and the connected resistance is 20,000 ohms, S_1 immediately re-closes, energises the line PQ, and relay B operates, retaining itself through B_3. The opening of B_1 adds 100 ohms to R_a. Opening of B_5 de-energises A, which, after a brief delay, releases, and A_1 short-circuits the 10-ohm resistor. The value of R_a is now 100 ohms and the ohmmeter is on its second range. S_1 will, however, still be closed, and relay C is now connected to line PQ by B_4, so that the process will be repeated and each relay operates in turn until relay D operates, making R_a 10,000 ohms. Then S releases, by reason of its delay, before E has operated and D, energised through D_3, remains operated. The ohmmeter now indicates the value of connected resistance at some 65 per cent of f.s.d.

(iii) *Resistance disconnected.*—When the measured resistance is disconnected so that the resistance between terminals is in effect infinite, S_1 re-closes and operation of the relays is resumed. When the last relay F operates, Y is de-energised by F_2 and releases, transferring S_1 to the control of relay X. Since S_1 is closed, X operates and de-energises F, which releases, but the meter remains on the highest range because Y_1 is open.

(iv) *Other details.*—It remains to describe the purpose of contacts A_2, B_2, C_2 and D_2. As stated, relay S has an operate/release ratio of 2 : 1 and a ratio of this order is unavoidable if definite operation of the relay is desired once the armature has commenced to move. As a result, after a change of range, relay S does not release unless the value of the resistance being measured is such as to reduce the current in it below the release value. In consequence a further, and undesired, change of range might be initiated. To avoid this, the value of R_a is temporarily increased, as each of the relays B to E operate, to that of the next higher range, and it is not until the preceding relay has released, after a brief delay, that the correct value is restored by the closing of the contacts A_2, B_2, etc. This ensures that after each switching operation relay S is positively released if the current flowing in its coil has a value near that at which it would remain released; a further change of range will not take place unless S_1 re-closes. Positive indication of range is given by the 12-volt 0.18-amp indicator lamps connected as shown.

Correction for variation of the internal resistance of the cell is arranged by making the 10-ohm section of R_a variable as a pre-set control and adjusting it from time to time so that when the ohmmeter is connected to a standard 10-ohm resistance contained within its case, it reads correctly.

Details of the relay windings are given in Table I. Contacts have normal adjustment except in the case of the retaining contacts B_3..F_3 which are arranged to close as or before B_1..F_1 open.

Separate heater windings are used for the voltmeter (6.0 volts) and the amplifier (6.3 volts) valves. A d.c. supply of 12 volts for the relays and lamps is provided by a bridge rectifier with reservoir condenser and no additional smoothing. H.T. at 225 volts is obtained from a half-wave rectifier, the total current is 20 mA.

Performance

In practice automatic range selection is extremely convenient. With the arrangement described and with the supply to the relays at 12 volts, the total time to reach the sixth range is approximately 0.6 second, which is just a satisfactory interval in which to turn the eyes from test prods to meter. The operating time can be varied within fairly wide limits by altering the relay voltage.

TABLE I

Relay	No. of Turns	Wire gauge (Copper)	Resistance (ohms)	Copper slug
S	25,000	44	3,000	none
X	8,000	38	350	none
Y	8,000	38	350	armature end
A	8,000	38	350	heel end
B-F	(i) 4,600	38	190	armature end
	(ii) 2,600	36	160	armature end

Except on the extreme ranges all readings lie between 28 per cent and 80 per cent of f.s.d. From 1 ohm to 10 megohms the limits are 9 per cent to 90 per cent of f.s.d. Stability of zero and of maximum scale settings is good and the operating point of relay S seldom needs adjustment unless there are large variations of supply voltage. There is an adequate overlap of ranges to take care of normal variation in the operating current of S.

By opening switch M any range may be selected by manually operating the appropriate relay and released by operating X. For this, the relay armatures are made accessible through a flexible dust cover.

It will, of course, be realised that range switching takes place in one direction only, and that if a continuously variable resistor is connected to the ohmmeter no change of range will occur with reduction of value. In practice this causes no inconvenience, since momentary opening of the circuit produces immediate selection of the correct range.

The principle of automatic range selection may be applied to a voltmeter, and protection against the hazard is, with a valve voltmeter, not particularly difficult. But since three or four ranges suffice for most requirements and a group of measurements mostly need the use of one or two adjacent ranges only, automatic selection is of doubtful value.

Television Aerials

FOR reception in fringe areas, two high-gain multiple-array television aerials have been introduced by Aerialite, Ltd., of Castle Works, Stalybridge, Cheshire. The model 64 consists of a folded dipole, one reflector and two directors, giving a power gain of 10.6db, a front-to-back ratio of 16.9db and an acceptance angle of 76 deg. It has a bandwidth of just over 4Mc/s when centred on 60Mc/s. The model 69 is, in effect, two of the above models 64 placed side by side, giving a forward gain of 13db and narrowing the acceptance angle to 68 deg. Both models are constructed in light alloy filled tubing, with steel masts and cross-pieces. Chimney brackets are provided for mounting, but care should be taken here since the arrays (at least 12ft high and 10ft long) may impose a strain on weak chimney stacks in high winds.

Corrections

In Fig. 3 of the article "Simple Valve Voltmeter" page 432, December, 1950, issue, the resistor R_{13} should be 4.7 kΩ and not 47 kΩ as shown.

In the concluding part of "Loudspeaker Cabinet Design," in the December, 1950, issue, the penultimate sentence of the middle paragraph of column 1, page 437, should read: "The resonance at f_2 which is above f_v indicates an increase in the sound output of the system, while that at f_1, which is below f_v, indicates a decrease."

WORLD OF WIRELESS

Notes and News ✦ Personalities ✦ Industry ✦ Meetings

R.N.V.(W.)R.

DETAILS of the growth of the Royal Naval Volunteer (Wireless) Reserve, which are given in the current issue of *The Communicator*—the journal of the Communications Branch of the Royal Navy—show that recruitment is steadily increasing, and has now passed the 500 mark.

In addition to the training facilities at the R.N.V.R. Divisional Headquarters, training centres are now established at Aberdeen, Bath, Birmingham, Bradford, Bramcote, Grimsby, Leicester, Manchester, Northampton, Norwich, Southend, Stockton and Yarmouth. Training facilities are also available at smaller centres at Cambridge, Derby, Exmouth, Rugby, Sheffield and Sunderland. Plans are understood to be in preparation for five other centres to be opened in the near future.

R.A.M.A.C.

THE appointment of a new secretary of R.A.M.A.C. (Radio Marine Associated Companies), the international organization of companies operating marine radio services, brings into the news an association about which little has been published.

Twelve companies are associated with Marconi's as members of the organization—the charter of which states that among its objects are the fostering of all technical developments relating to marine wireless communications, radio and electronic aids to navigation and all such devices as can be applied to the safety of life and property at sea. This is achieved by an exchange of information on marine radio matters between the member companies (in Canada, Australia, South America, South Africa and Europe) and by providing a maintenance organization at the world's principal ports. The new secretary, who succeeds J. Connell—retiring from the post which he has held since the formation of the association three years ago—is E. Fost.

PLAYBACK console for tape and disc recordings at the Berlin Station RIAS (Radio in the American Sector) which radiates on a frequency of 989 kc/s with a power of 100 kW.

Marconi House, London

THE announcement by Marconi's Wireless Telegraph Co. and the Marconi International Marine Communication Co. that their registered address is now at Marconi House, Strand, London, W.C.2, means a renewal of old associations with the early days of wireless, and particularly of broadcasting. The main business of both companies will continue to be conducted from Marconi House, Chelmsford, but the Export Department of M.W.T. and the Contracts Division of the M.I.M.C. will be in the Strand building (Tel.: Temple Bar 1577), which was vacated in 1933.

In announcing the change Marconi's recall that it was on the seventh floor of this building that British broadcasting was born when they first made regular broadcasts from 2LO in 1922; we can add that it was in the same building that *Wireless World* first saw the light of day. Later in the same year the British Broadcasting Company was formed and took over 2LO.

PERSONALITIES

Sir Thomas G. Spencer, M.I.E.E., managing director of Standard Telephones and Cables, Ltd., has been elected chairman of the Board of the company in succession to the late Sir Frank Gill. He has been with the company, which was formerly the Western Electric Co., since 1907. Sir Thomas, who was founder and first chairman of the Telecommunication Engineering and Manufacturing Association, will continue to hold the position of managing director of S.T.C.

R. W. Haddon, C.B.E., who received a Knighthood in the New Year Honours, is deputy chairman of Associated Iliffe Press, Ltd., and a director of Iliffe & Sons, Ltd., our publishers, and is chairman and managing director of Farmer and Stock-Breeder Publications, Ltd.

J. A. Dickson, who is awarded an M.B.E. in the New Year Honours, is manager of the Gramophone Company's works manufacturing special products. He was with the Marconiphone Co. in the early days of broadcasting and then transferred to the Gramophone Co. Mr. Dickson was manager of the Production Planning Department of the Hayes factory from 1936-1940, when he relinquished this post to take up his present appointment.

Leonard Rushforth, B.Sc., M.I.E.E., who is Head of the Pre-production and Engineering Section of the B.T.H. Research Laboratory—which he joined in 1932—and was a prominent member of the team responsible for the development of magnetrons and other electronic devices in the radar field, is made an M.B.E. in the New Year Honours. He was sent by the Government to the U.S.A. in 1943 and again in 1944 on investigational and experimental work on the magnetron.

T. A. Simpson, who joined the Marconi International Marine Communication Co. as a member of the sea-going operating staff in 1913, has been appointed deputy general manager. In 1917 he was appointed to the instruction staff at Marconi House, London, and between 1931 and 1946 served on the company's overseas staff. Since 1946 he has held administrative posts at the company's head office.

T. A. SIMPSON

Bruce Wilkinson, B.E., has been appointed managing director of Electronic Tubes, Limited, Kingsmead Works, High Wycombe, the company specializing in the manufacture of valves and cathode-ray tubes acquired by E.M.I. last year. He was commercial director of E.M.I. Factories, Ltd., which he joined after coming in 1946 to this country from Australia where he had been with Amalgamated Wireless Australasia, Ltd. for 16 years. For some of this period he was in control of the A.W.A. Research Laboratories.

IN BRIEF

Licences.—At the end of November the number of receiving licences current in the United Kingdom was 12,334,150, including 549,200 television licences. The increases over the previous month's figures were 17,300 and 38,050 respectively.

BRUCE WILKINSON
(See "Personalities")

Television by Wire.—Central Rediffusion Services, Ltd., announce that they have developed a system of television rediffusion which will be introduced in "fringe areas." A special receiver, the a.f. side of which will also be used for the normal sound broadcasting relay system, will be provided at a weekly rental. The company is installing a similar system in Canada which provides for the simultaneous distribution of two television programmes in addition to the choice of sound programmes.

Emergency V.H.F.—The Ministry of Civil Aviation announces the use of 121.5 Mc/s for distress purposes and for communication in the United Kingdom (in case of emergency) between aircraft and aerodromes not normally used by international air services and between aircraft in rescue operations.

I.P.R.E.—C. H. Gardner, of Mullard Electronic Products, Ltd., has been re-elected president of the Institute of Practical Radio Engineers. This will be his second year of office.

Radio Heating.—K. A. Zandstra, Head of the High-Frequency Department of Philips Electrical, Ltd., has been awarded the Bessemer Premium by the Society of Engineers for his paper "High-Frequency Heating in Industry." A reprint of this paper, which approaches the subject of radio-frequency heating methods in mass production with a view to introducing it to engineers and executives, is at present in preparation by Philips.

B.S.I.—H. A. R. Binney, C.B., who has held a number of Government posts and has represented this country on numerous international conferences has been appointed director and secretary of the British Standards Institution in succession to the late Percy Good.

Mis-use of M.I.E.E.—The Council of the Institution of Electrical Engineers has, during the past three years, taken action in thirty-three cases where there has been mis-use of the designation of membership of the Institution. In only one case has it been necessary to have recourse to the Courts.

Factory Visits.—The Council of Industrial Design invites manufacturers who are willing to receive visitors at their factories during the Festival of Britain to send particulars to the Council, which will compile a list of such firms and arrange for it to be available to visitors on presenting a trade or business card at the Industrial Information Bureaux at the official exhibitions. Manufacturers who would like their names to appear on the list should write to S. D. Cooke, Council of Industrial Design, Tilbury House, Petty France, London, S.W.1, giving details of their products, the approximate number of employees in the factory, the most convenient days and hours for receiving visitors and the person to whom visitors should apply in advance.

Edison Swan advise us that their magnetic tape recorder was used to record the opening ceremony of the Gibraltar Legislative Council by H.R.H. the Duke of Edinburgh to whom a copy of the recording was given.

I.A.L.—International Aeradio, Ltd., are to be responsible for the installation and maintenance of all ground radio equipment at 28 aerodromes in East Africa ranging from the international airport at Eastleigh to small airstrips. Administration will be handled through International Aeradio (East Africa), Limited.

OBITUARY

Dr. Edward Mallett, M.I.E.E., who had been principal of Woolwich Polytechnic since 1932, died on December 10th at the age of 62. Prior to his appointment at the Polytechnic he was assistant professor at the City and Guilds College. He was chairman of the I.E.E. Wireless Section in 1936-37.

MEETINGS

Institution of Electrical Engineers

Radio Section.—"Radio Valve Life Testing" by R. Brewer on February 7th.

Discussion on "Is there an Optimum Speed for a Gramophone Record?" to be opened by G. F. Dutton, Ph.D., B.Sc.(Eng.), on February 19th.

Informal Meeting.—Discussion on "The Inventor, Engineer and Manager" to be opened by P. P. Eckersley on February 12th.

The above meetings will be held at 5.30 at the I.E.E., Savoy Place, London, W.C.2.

Cambridge Radio Group.—"Crystal Diodes" by R. W. Douglas, B.Sc., and E. G. James, Ph.D., and "Crystal Triodes" by T. R. Scott, B.Sc., at 8.15 on February 13th at the Cavendish Laboratory, Cambridge. (Joint meeting with the Cambridge University Wireless Society.)

North-Eastern Radio Group.—"Determination of Time and Frequency" by H. M. Smith, B.Sc., at 6.15 on February 5th at King's College, Newcastle-on-Tyne.

North-Western Radio Group.—Informal lecture on "Some Engineering Aspects of the Development of Television Broadcasting" by J. L. Bliss, at 6.30 on February 21st at the Engineers' Club, Albert Square, Manchester.

Northern Ireland Centre.—"Some Aspects of Noise and Radio-Frequency Disturbance from Gas-filled Tubes" by Prof. K. G. Emeleus, M.A., Ph.D., at 6.45 on February 13th at Queen's University, Belfast.

South Midland Radio Group.—"Some Electrical Methods of Measuring Mechanical Quantities" by F. J. Woodcock at 7.0 on February 20th at the Winter Gardens, Malvern.

"Fifty Years' Development in Telephone and Telegraph Transmission in Relation to the Work of Oliver Heaviside" by W. G. Radley, C.B.E., Ph.D. (Eng.), at 6.0 on February 26th at the James Watt Memorial Institute, Great Charles Street, Birmingham.

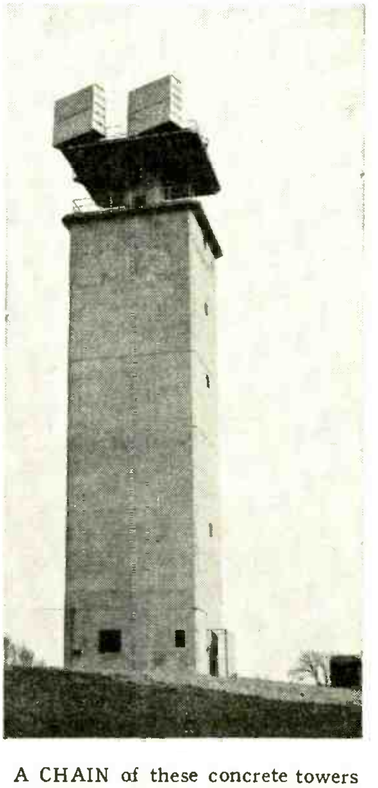
Southern Centre.—"Radio Receivers' Testing Equipment" by E. J. Finn at 7.30 on February 7th at the Signal School, R.M. Barracks, Eastney, Portsmouth.

Irish Branch.—"Fifty Years of Telecommunications in Ireland" by J. W. O'Neill, B.A., at 6.0 on February 15th at Trinity College, Dublin.

London Students' Section.—Visit to the G.P.O. Research Station at Dollis Hill at 2.30 on February 14th.

Scottish Students' Section.—"Some Aspects of Sound Reproduction" by D. T. N. Williamson at 7.30 on February 9th at Darling's Regent Hotel, Waterloo Place, Edinburgh, and at 7.30 on February 12th at The Engineering Centre, Sauchiehall Street, Glasgow.

Discussion on "High-Quality Sound



A CHAIN of these concrete towers carrying 10-ft square horn radiators are being erected by the American Telephone and Telegraph Co., to relay television across the States.

Reproduction" at 7.30 on February 28th at Darling's Regent Hotel, Waterloo Place, Edinburgh.

British Institution of Radio Engineers

London Section.—"Electronics and Air Transport" by C. H. Jackson, B.Sc., A.F.R.Ae.S., at 6.30 on February 21st at the London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1.

Scottish Section. — "Multi-Station V.H.F. Communication Systems using Frequency Modulation" by W. P. Cole, B.Sc., and E. G. Hamer, B.Sc., at 6.45 on February 1st at the Scottish Lyceum Gallery, Atholl Crescent, Edinburgh.

Merseyside Section.—"A Transmitter for an Experimental 8-Channel Carrier Wire-Broadcasting System" by R. G. Kitchenn, B.Sc. (Eng.), at 7.0 on February 7th at Electricity Service Centre, Whitechapel, Liverpool.

South Midlands Section.—"A Survey of Television Development and its Problems" by H. J. Barton-Chapple, B.Sc., at 7.15 on February 14th at the headquarters of the East Midlands Electricity Board, Coventry.

North-Eastern Section.—"The use of Foster's Theorem in Circuit Design" by E. Williams, Ph.D., at 6.0 on February 14th at Neville Hall, Westgate Road, Newcastle-on-Tyne.

West Midlands Section.—"Power Rectifiers" by J. C. Milne at 7.0 on February 28th at Wolverhampton and Staffordshire Technical College, Wulfruna Street, Wolverhampton.

Television Society

London Meetings. — "The First British Multi-Channel Receiver" by W. D. Asbury, K. M. B. Wright and W. M. Lloyd, B.Sc., (Bush Radio) at 7.0 on February 8th.

"Television from Calais—the First Cross-Channel Broadcast" by W. D. Richardson and W. N. Anderson (B.B.C.) at 7.0 on February 23rd.

Both meetings will be held at the Cinema Exhibitors' Association, 164, Shaftesbury Avenue, W.C.2.

Leicester Centre.—"Time Bases" by C. H. Banthorpe at 7.0 on February 15th at the Leicester College of Technology, The Newarkes, Leicester.

British Sound Recording Association

"The Application of Elementary Mechanics to Sound Recording" by J. F. Doust at 7.0 on February 16th at the Royal Society of Arts, John Adam Street, London, W.C.2.

Institution of Electronics

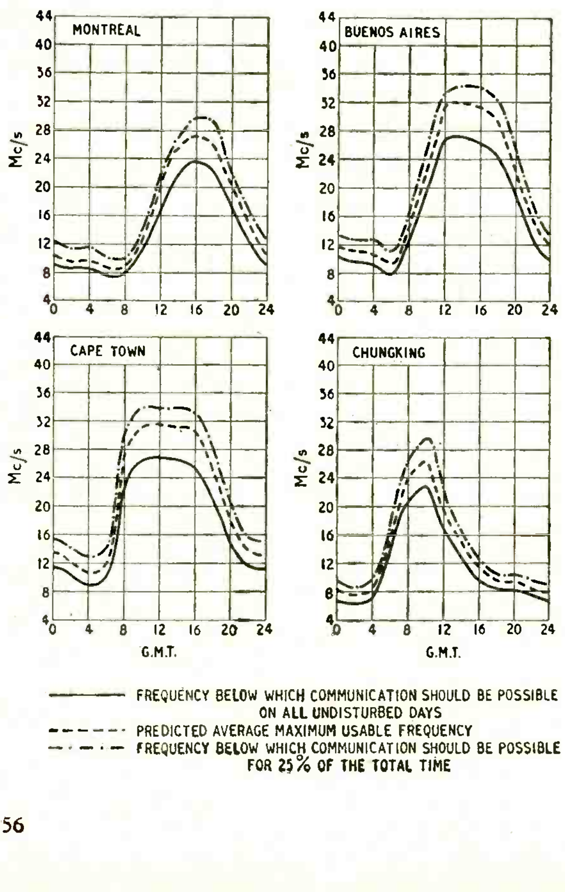
Midlands Branch.—"Electronic Aids in Engineering, Research and Development" by J. R. Cornelius, at 7.0 on February 6th at the Warwick Room, Imperial Hotel, Temple Street, Birmingham, 2.

SHORT-WAVE CONDITIONS

December in Retrospect : Forecast for February

By T. W. BENNINGTON (*Engineering Division, B.B.C.*)

DURING December the average maximum usable frequencies for these latitudes decreased both by day and night. The day-time variation was in accordance with a subsidiary decrease which usually occurs at midwinter, whilst that at night was in accordance with the usual seasonal trend, whereby the night-time m.u.fs reach their lowest values around the winter solstice. They should now begin to increase. Both day and night m.u.fs were *much* lower than at the same time last year, due to the decreased sunspot activity.



Day-time working frequencies were moderately high and those for night-time very low. Once or twice frequencies up to 32 Mc/s were workable over long distances, but the highest day-time frequencies were more often of the order of 22 Mc/s. At night only the lowest short-wave frequencies were regularly usable.

Less Sporadic E was observed during the month than during November. Sunspot activity was, on the average, somewhat higher than for several months past.

There was less ionospheric disturbance than during November, though several storms did occur. The most severe of these were on 1st-2nd, 13th-17th, 22nd-24th and 26th-27th. No Dellinger fade-outs were reported during the month.

Forecast.—During February m.u.fs in these latitudes should be slightly higher, both by day and night, than during January. Long-distance working frequencies should therefore be relatively high by day and low by night over most circuits. On north/south circuits day-time frequencies should increase quite appreciably compared with January, and those of the order of 26 Mc/s become regularly usable. On east/west circuits there should be little change from January in the day-time frequencies, where the highest regularly usable should be of the order of 23 Mc/s. At night-time working frequencies should become slightly higher over all circuits, the highest regularly usable frequencies being of the order of 8 Mc/s at the worst time of night. Medium-high frequencies—such as 15 Mc/s—will be usable for longer day-time periods than during January.

Sporadic E capable of sustaining propagation on very high frequencies is unlikely to be prevalent. Ionospheric storms are not usually particularly prevalent during February, though those which occur during the night often have serious effects on short-wave communication.

The curves indicate the highest frequencies likely to be usable over four long-distance circuits from this country during February.

Germanium Diodes

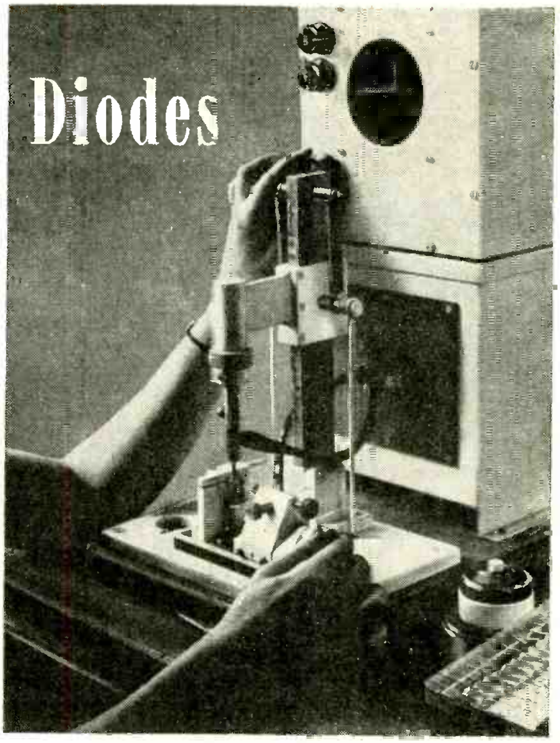
Uses, Characteristics and Method of Manufacture

By R. T. LOVELOCK, A.M.I.E.E.
(The General Electric Co., Ltd.)
and J. H. JUPE, A.M.I.E.E.

FROM the earliest days of radio there has been a use for dry contact rectifiers. These rectifiers are all based on the phenomenon of asymmetrical conduction between a metal and a semi-conductor. The semi-conductor materials are those which have electrical conductivity intermediate between metals and insulators. They are usually much poorer conductors than any of the metals and much better than any of the insulators. Infinite gradations exist, however, and some materials exhibiting the characteristic semi-conductor phenomenon of having free electrons, conduct almost as well as metals, while others are almost insulators in the general engineering sense of the word. When a suitable combination of a semi-conductor and a metal is made, a "barrier" is created at the point of contact and for small applied potentials the resistance at the barrier in one direction is much greater than in the other, and where the difference is great enough the phenomenon can be used as the basis of a rectifier. Examples used in the early days of radio were combinations of carborundum/steel, zincite/bornite, silicon/copper, galena/copper, etc. These rectifiers were quite efficient electrically, but were very unreliable, extremely sensitive to vibration and fell into disuse when the thermionic diode appeared.

Later, new types of dry rectifiers were developed, copper/copper oxide, selenium/white metal alloy and copper/copper sulphide and have become well established, chiefly in the power-frequency and audio-frequency fields because their high electrical capacitance renders them very inefficient at high radio frequencies. Suitable copper oxide rectifiers can, however, be used up to about 1 Mc/s.

Of recent years the increasing use of centimetre wavelengths has led to the need for a rectifier with lower capacitance than the usual thermionic diode. The first type developed was a modern version of the silicon rectifier and was widely used during the 1939-45 war for radar work. This form of rectifier is substantially more stable than the earlier type of silicon rectifier, but is liable to be burnt out by transient surges of current induced in its circuit. Later developments have shown that a crystal rectifier based on germanium can be extremely satisfactory, has exceptional mechanical stability and cannot easily be damaged electrically.



Special oscilloscope used for observing the electrical characteristic of germanium diodes whilst in the process of assembly.

It has not entirely displaced the modern silicon rectifier which is still of use where high forward conductivity at very high frequencies is important, but it is now clear that germanium rectifiers are likely to have a wide range of uses in radio frequency circuits and may even displace silicon types.

In a crystal rectifier the area of contact must be small if the shunt capacitance is to be minimized and this is achieved by using a springy, pointed wire to make end-on contact with the semi-conductor. A particularly good construction for a germanium rectifier and one adopted by The General Electric Co., Ltd., is shown in Fig. 1. It consists of an annealed glass capsule into which is sealed two metal tubes. Through each of these tubes passes a metal stub which is attached to a semi-flexible connecting wire. One stub carries the contact wire (whisker) and the other the germanium crystal. The two stubs are welded to the tubes to ensure stability at the high

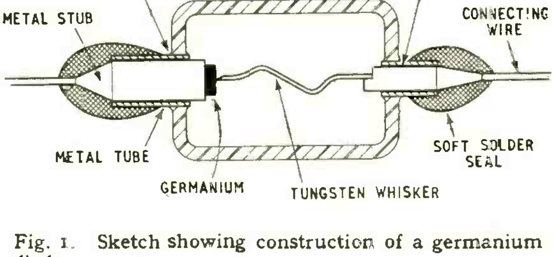


Fig. 1. Sketch showing construction of a germanium diode.

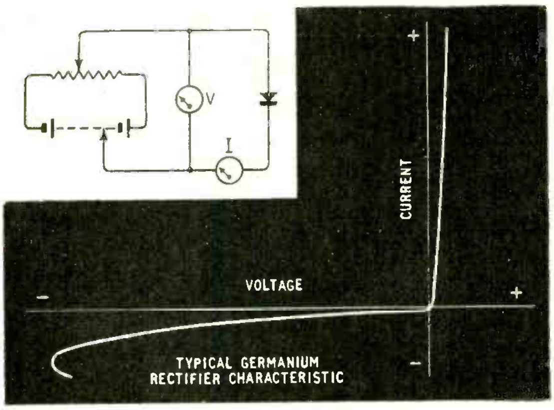


Fig. 2. Typical current/voltage characteristic of a germanium diode.

temperatures brought about when the rectifier is soldered into its circuit, and the joint between the stubs and the tubes is sealed with soft solder to render the assembly moisture-proof.

Characteristics.—The direction of current flow corresponding to low resistance (forward direction) varies with the composition of the crystal and the material of the whisker, but, of course, the finished rectifier is clearly marked to ensure correct connection.

A typical current/voltage characteristic for a rectifier using almost pure germanium, drawn to a linear scale, is shown in Fig. 2. As the "anode" is made more positive the current increases very rapidly and exponentially, but later becomes linear in form. In the reverse direction, with the "anode" made negative, very little current will flow at first, but as the voltage is increased the reverse current will rise rapidly until at a potential known as the "turnover voltage" it changes slope, i.e., the rectifier resistance becomes negative.

With regard to the effect of temperature the forward resistance, reverse resistance and the turnover voltage all decrease with increasing temperature and *vice versa*. The working temperature range of the rectifier is $-100°C$ to $+120°C$ and typical characteristics for one type are plotted in Fig. 3 to a double logarithmic scale at three temperatures. It should be noted that the variation with temperature is very much less for larger input voltages. When antimony is added to the germanium the rectifier has an extra low forward resistance (see Fig. 4) and can enter into competition with silicon rectifiers for v.h.f. working. This type of rectifier has a turnover voltage of about 10 volts.

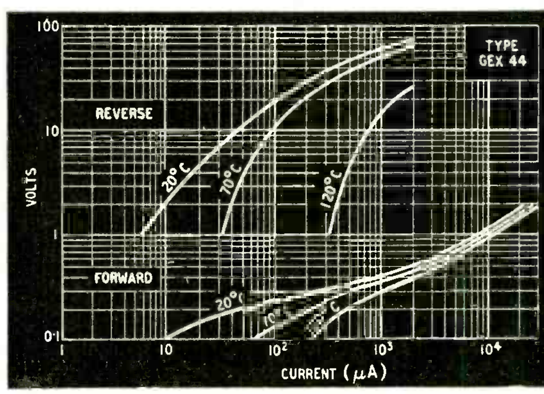
It is at high radio frequencies that the crystal rectifier enters into competition with the thermionic diode. It has a much lower shunt capacitance ($0.3\,\mu\mu F$ to $1.0\,\mu\mu F$), requires no heater and may thus easily be operated with both electrodes well above earth potential without introducing hum. Its life is indefinitely long, certainly above 10,000 hours, and it can be wired directly into a circuit and so avoid stray capacitances. Another advantage is that there is no "standing current," i.e., the current at zero voltage is nil, which simplifies metering circuits.

A point of difference between germanium crystals and thermionic diodes is that the forward resistance of crystals is lower than that of most miniature diodes, but the reverse resistance is also lower. The value of this reverse resistance is not usually objectionable and, by considering it in the circuit design, can generally be made to have a negligible effect.

The dynamic rectification characteristic of a typical rectifier is shown in Fig. 5 and the characteristic is maintained sensibly constant over the frequency range 0.1 Mc/s to 150 Mc/s.

When used in a series circuit or with very low values of load resistance, the efficiency of a germanium rectifier falls with increasing frequency, but useful output may still be obtained at frequencies above 500 Mc/s, a region where thermionic diodes tend to be very inefficient, due to their relatively large capacitance and to "transit time" effects. It should, however, be remembered that although the capacitance of germanium rectifiers is extremely small it is not a loss-free capacitance, and, therefore, when it is shunted across a tuned circuit of small total shunt capacitance there may be an appreciable fall in the value of Q, if the resonant circuit has very small losses.

The rectifiers will run continuously with a forward current of 50 mA, which gives a remarkably high power handling capacity for so small a component. Furthermore, the occasional passage of currents up



Above: Fig. 3. Graph showing the effect of temperature on the voltage/current characteristic of a germanium diode.

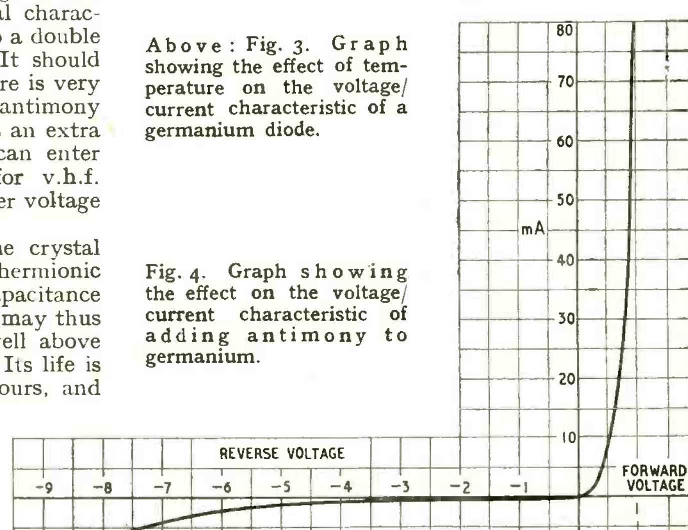


Fig. 4. Graph showing the effect on the voltage/current characteristic of adding antimony to germanium.

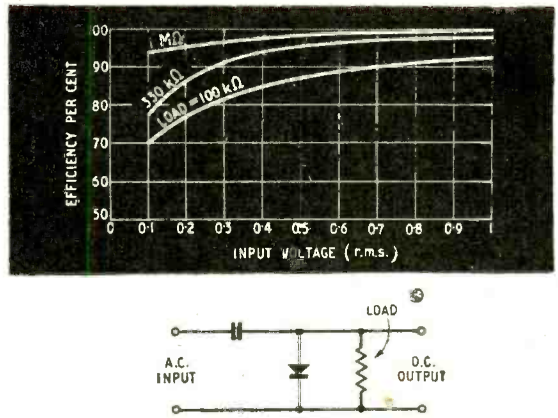


Fig. 5. Dynamic rectification characteristic of a germanium diode.

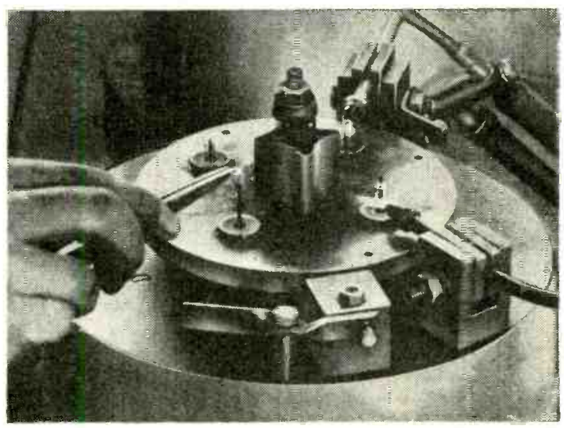


Fig. 6. One of the semi-automatic machines used in making germanium diodes.

to 0.5 amp in the forward direction, will cause no harm, providing that the duration does not exceed one second. This feature makes the rectifiers very dependable for use in domestic radio and television receivers.

A use for the germanium rectifier which is finding many applications is that of a non-linear circuit element and at all frequencies below about 1,000 Mc/s the freedom of the germanium rectifier from "burn-out" should cause it to replace the silicon mixer. It should be noted here that as a rough working rule the rectifiers with the lower values of turnover voltage generally prove to be more efficient at the extremely high frequencies. Another use for the mixer type of rectifier lies in extending the frequency range of multi-channel systems of wire communications. Hitherto copper-oxide rectifiers have been used in low-frequency modulators, but above a few hundred kilocycles per second their high capacitance creates difficulties and the germanium rectifier, which has similar static characteristics but a much smaller capacitance, and a much smaller size, is a considerably superior component in this type of circuit and will permit efficient operation at very much higher frequencies.

In the field of measurements the germanium rectifier is an interesting development because it permits the construction of direct-reading high-frequency indicating instruments for wide frequency ranges, without the use of delicate thermocouples.

As mentioned above earlier, germanium rectifiers can be given a negative resistance characteristic by suitable biasing. This opens up the possibility of operation as an oscillator and such oscillators have, in fact, been constructed. At present, however, their use is somewhat difficult because of the heat generated at the point of contact, which limits oscillation to very low and not particularly useful levels.

Production.—If rectifiers of the above types are to be produced for reasonably low costs the complex techniques of the laboratory have to be adapted to factory production lines using semi-skilled labour and a minimum of highly skilled supervision. The following outlines some of the ways of doing this and indicates the problems involved.

The germanium for these rectifiers must be of a peculiar quality in that it must contain an extremely small amount of impurity in a mass of otherwise pure material. The impurity of chief importance is arsenic and the desirable amounts are too small for reliable estimation by chemical or spectroscopic methods. From extrapolation on electrical characteristics, however, relative to known amounts of arsenic, it has been inferred that the amount of arsenic must be about one part in ten million. However, to obtain germanium approaching this degree of purity very elaborate precautions have to be taken and in general terms the aim of the chemists is to produce pure germanium.

Rectifiers made from such germanium will have a high reverse resistance. By adding antimony to the metal, however, rectifiers with a low forward resistance can be prepared.

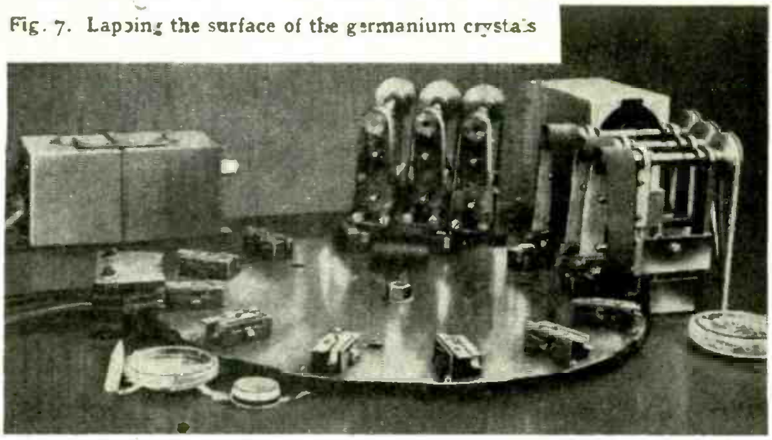
The basic source of the germanium is flue dust obtained by burning certain types of coal and the dusts yield ½-1 per cent germanium. The method of extraction was developed jointly by the G.E.C. and Johnson Matthey, Ltd., and the end product is pure germanium oxide which is reduced to the metal by heating in an atmosphere of hydrogen, followed by melting. Extreme care has to be taken in the melting process in order that additional impurities are not added to the oxide and the furnaces are operated in sealed enclosures with forced air circulation and with filters to remove all foreign matter from the air. Elaborate precautions are also taken to avoid contaminating the germanium by handling or contact with containers, etc.

The glass capsule, the stub containing the tungsten contact point (whisker) and the stub carrying the germanium globule are all formed on semi-automatic machines (Fig. 6) and after the end of the whisker has been suitably cut and conditioned, its stub is welded into the metal tube and the joint between the stub and the tube is hermetically sealed with soft solder.

The germanium globule is attached to its stub with a high melting point solder and half of the sphere is ground away and the circular surface is lapped flat to form the rectification area (Fig. 7). This area is then treated by an electro-chemical process to form a suitable surface for the whisker to contact. Finally, both components which will form the complete unit are chemically cleaned and thereafter stored in a clean dry atmosphere until finally sealed together as a completed rectifier.

The most critical process of assembly is the mating

Fig. 7. Lapping the surface of the germanium crystals



of the crystal and contact point and this operation is centred in machines which give micrometer control of position and contact pressure. Throughout the assembly operation the complete static electrical characteristic is under the observation of the operator, with the aid of a specially designed oscilloscope unit. After optimum adjustment of whisker and crystal to the desired characteristic, the crystal stub is welded into its sleeve and the joint is hermetically sealed with soft solder as before. Thus, with the exception of the joints between the globule and the stub all structural strains are taken by welded joints. This eliminates the possibility of any change when the rectifier is soldered into position or subjected to vibration. As an additional safeguard against change due to vibration, the face of the germanium is coated with a polymerizing resin immediately before assembly and the unit is heated to polymerize the bond. Finally, when these processes are completed, every rectifier is subjected to a vibration test greatly in excess of anything likely to be encountered during its normal usage.

The contact between the whisker and the crystal is only a nominal point and obviously must vary to a minute degree in size and shape. These factors, however, greatly affect the electrical characteristics and although there has been adjustment to an optimum position during assembly and a satisfactory rectifier has been created, its characteristics can be still further improved by subjecting it to a final forming process. This process utilizes currents of polarity, magnitude and duration which depend on the initial characteristic of the rectifier. In order to reduce the cost of manufacture an instrument has been devised, (Fig. 8) based on automatic telephone equipment and which will measure the characteristics, decide on the appropriate current treatment, apply this treatment and finally retest the rectifier before it is passed into store. This instrument is entirely automatic in operation.

With so many delicate and inter-related processes the advisability of using quality control is substantial and every day a small percentage of the total production is drawn at random from all stages of the production process where any variation can occur. These daily samples are measured in every possible way by laboratory technicians and the results are assessed by statistical methods. In this way, warning is given of the slightest drift away from optimum conditions and incipient faults can be detected and corrected before faulty production has occurred.

Fig. 8. Automatic routiner used for testing germanium diodes.

WORLD LISTENING

A COMPANION booklet to the well-known "World-Radio Handbook for Listeners" has now been published, concurrently with the latest edition of the handbook, by O. Lund Johansen, of Copenhagen. "How to Listen to the World," as it is called, sets out to help listeners to get the best from their receivers by giving hints and tips on short-wave reception. Space is devoted to such matters as the propagation of short waves, various types of receiving aerial, zonal times and tables giving in general terms what may be expected to be the best frequencies for reception in the Northern and Southern Hemispheres from September to April. It costs 1s 6d.

The 1950-51 edition of "World-Radio Handbook for Listeners," which costs 6s 6d, has been completely reset and includes considerable additional matter.

Both publications are printed in English and are obtainable in this country from Surridge, Dawson & Co., Ltd., 101, Southwark Street, London, S.E.1.

Another book on world listening, but covering a slightly different field, is "Op-Aid," published by the Amalgamated Short-Wave Press, 57, Maida Vale, London, W.9, price 1s 6d. It includes such useful data as international prefixes and amateur "district" or "state" calls, QSL bureaux, and amateur codes and abbreviations. It does not give lists of stations.

Vector Diagrams

2.—The Diagram Itself

HOW SHOULD THE VECTORS BE ARRANGED?

By "CATHODE RAY"

LAST month we did some preliminary spade work, clearing away causes of misunderstanding by classifying the various ways in which the voltages in a circuit can be denoted and reckoned. You may remember that according to one method a voltage is called positive when it results in a fall of potential in the direction considered, while another method regards a rise in potential as positive. So when we are told that the voltage between two points *a* and *b* is + 100, we do not know which point is positive unless we are also told (i) the direction in which the voltage is being reckoned, and (ii) whether a positive value signifies a rise or a fall. Some people complicate the system by regarding rises of potential as positive when they are e.m.fs and falls in potential as positive when they are across resistances, but that raises the question "What is an e.m.f.?" which we found to be rather trickier than is sometimes admitted.* There seems to be less risk of going wrong if one sticks to either rises or falls, because the total of either completely around any circuit, taking proper account of + and − signs, is bound to be zero, which is a useful check. I recommended reckoning in rises, because a rise is the effect of a positive e.m.f., which is the driving force of a positive current. A fall is a negative rise. A convenient method of identifying a voltage is the double subscript notation; V_{ab}, for example, which specifies (i) the points between which it exists (*a* and *b*), (ii) the direction considered (*a* to *b*), and (iii) which point is the more positive, provided that it is known whether the rise or the fall system is in use. If rises, then a positive V_{ab} means *b* more positive than *a*; and vice versa.

All this applies to either d.c. or a.c. But with a.c., except in purely resistive circuits, it is not merely a question of positive or negative but of all the shades of phase difference in between those two extremes. And that is where vector diagrams are so useful. One could, of course, draw a voltage/time or current/time diagram, such as Fig. 1, to show the voltage or current at every instant during each cycle, and find the phase difference from that. Fig. 1 informs us that the current is quarter of a cycle behind the e.m.f., which according to the usual scale of 1 cycle = 360° is a phase lag of 90°. One disadvantage of this sort of diagram is the troublesomeness of plotting and drawing it—unless it is provided by a good oscillograph. Another disadvantage, even with the oscillograph, is that it is not at all easy to read off the phase differences accurately in degrees. The chief value of this type of diagram is for showing the waveform; but when most of the time we know or assume that the waveform is sinusoidal, to draw the waveform diagram merely to show phase differences is like burning down the house to roast the dinner.

When the waveform can be taken for granted, a much simpler phase diagram can be made by drawing lines at angles equal to the phase angles. The distinction between + and −, or between an angle and the same angle plus or minus 180°, is indicated by an arrow head to show which of the two possible ways it is pointing. The technical term for this distinction is *sense*. Lastly, the lengths of the lines conveniently represent the magnitudes of the voltages or currents (or, for that matter, magnetic fluxes, electric fields, sound pressures, or anything else that is varying with the same waveform).

But, you may say, how does the fixed length of a line represent a quantity that is continuously varying? This aspect of vector diagrams is so fully explained in the books on a.c. that I won't do more than summarize what most of you probably know very well already. Strictly speaking, the length of the line or vector represents the peak value. The vector is imagined to be pivoted at the end farthest from the arrow head, and to be rotating at a rate of one revolution per cycle. The distance from the arrowhead end to a horizontal line drawn through the pivot represents the instantaneous value.

In Fig. 2, for example, the length of the vector OP represents the peak value, to some convenient scale. And the shortest distance, PQ, between P and the horizontal line through O, represents to the same scale the instantaneous value at the moment when the rotation of OP has brought it to the position shown. Positive frequency is represented by anticlockwise rotation, beginning at "3 o'clock" as zero. So a vector drawn along OQ, representing

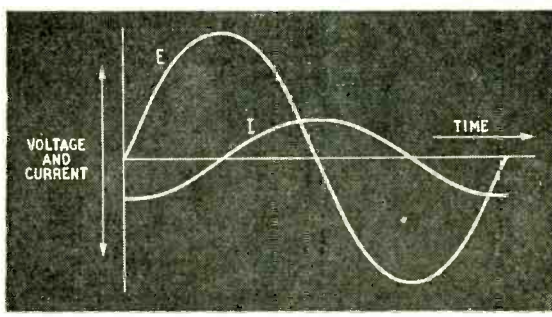


Fig. 1. This type of diagram shows amplitudes and phase differences, but for those purposes alone is needlessly difficult to draw.

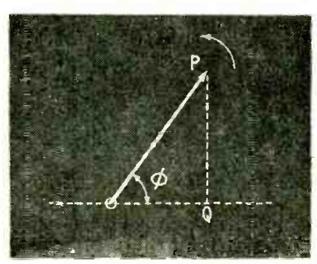


Fig. 2. Here the amplitude and phase of a sine wave is shown more clearly than in the Fig. 1 type of diagram, and with much less effort.

* *Wireless World*, December, 1950, p. 453.

something just on the starting line of a cycle, would have a negative phase angle ($-\phi$) relative to OP: and the phase angle of OP relative to OQ is $+\phi$. If you were to plot the varying length of PQ against phase angle or time, you would get a sinusoidal waveform as in Fig. 1.

Often there is no need to bother about instantaneous values, in which case the imaginary rotation can cease. And since with a sine waveform the r.m.s. value is equal to the peak value divided by $\sqrt{2}$, it is represented by 0.707 times the length of the vector. But as all the waveforms are assumed to be sinusoidal, all are subject to this same conversion factor, and it is easier (if one wants to work throughout in r.m.s. values) to do the conversion by leaving the lengths of the vectors alone and just altering the voltage scale. It must be remembered then that the verticals have to be multiplied by $\sqrt{2}$ to give instantaneous values.

So much, and more, the books generally explain thoroughly and well. Where most of them fall down is over the sort of thing we discussed last month and recapitulated at the beginning of this instalment. They usually fail to warn the reader that there are several recognized (to say nothing of unrecognized!) ways of drawing a vector diagram to represent a given situation. This means—still more alarming thought—that there may be several possible ways of interpreting a given vector

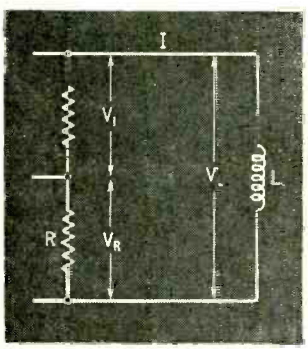


Fig. 3. A sample circuit diagram for demonstrating various ways of drawing vector diagrams

Fig. 4. How different people might draw the vector diagram relating to Fig. 3. Only (d) can be called definitely wrong

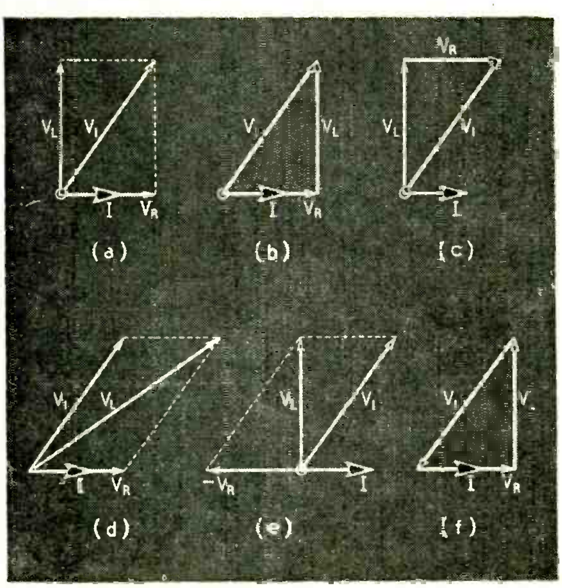


diagram. With experience one can usually guess correctly which conventions the author of the diagram is using and so put the right interpretation on it. But until the experience is gained, the student may be confused.

The risk of misunderstanding increases, of course, with the complexity of the circuit. Let us watch what an imaginary Mr. X makes of even such a simple circuit as Fig. 3. He has labelled it in the way I personally can't recommend, but as it is the most commonly seen in books it is difficult to blame him. Now he is beginning to draw a vector diagram. He has started off quite correctly with the current vector, because I is the one thing common to all parts of the circuit. And in the absence of any particular information about its phase at the moment under consideration, he is free to choose whatever phase he likes for the first vector. It is the relative phases that are important. He has quite sensibly decided to draw it at the conventional zero angle, pointing to 3 o'clock.

Next he remembers that the current through a resistance is always in phase with the voltage across it, so he draws V_R in phase with I to show this (Fig. 4 (a)). He also remembers that the current through an inductance lags the voltage by 90°, so he draws the V_L vector 90° in advance of the I vector. Lastly he decides that the voltage V_1, across the upper resistor, must be the source of e.m.f. in the circuit, and equal to V_R and V_L combined. So he proceeds to combine them by the well-known process of "completing the parallelogram," finally drawing in the V_1 vector as the diagonal.

Mr. Y, faced with the same circuit, adopts the same procedure as far as V_R; but he decides in advance that V_1 is the resultant of V_R and V_L, and makes the vector V_L start where V_R left off, giving the somewhat neater diagram shown as Fig. 4 (b).

Mr. Z has the same ideas about vectorial addition, but happens to take V_L first, yielding Fig. 4 (c).

Mr. P looks carefully at Fig. 3 and decides that obviously $V_L = V_1 + V_R$. So after he has drawn the I and V_R vectors in phase he gets his V_1 vector by cribbing it from the other fellows' diagrams. Then he completes the parallelogram to get Fig. 4 (d).

This is too much for us, and we intervene to point out that, although it doesn't altogether look like it, V_1 is in effect the e.m.f.; and V_R, although also across a resistance, must be deducted from V_1, because it is a voltage drop. So after a bit of prompting he produces Fig. 4 (e), and although we assure him that it is the correct answer—or one of them—he is not at all happy about the vector for V_R pointing opposite to I when the others have it in phase; and he is still not clear why what looks so obvious from the circuit diagram can be wrong, and if so how was he to know?

I have a good deal of sympathy with Mr. P.

Lastly Mr. Q comes along and, being an admirer of Kirchhoff, achieves yet another version, Fig. 4 (f). There can be no snag about this, he says, because he has drawn all the vectors head to tail, so wherever you start you arrive back at the same place, having completed a lap of the course, and the total voltage is zero, in accordance with the Second Law.

We admire Mr. Q's ingenuity, but are a little doubtful about how far his diagram conforms to generally accepted ideas about vectors; in particular, whether it is allowable for every corner to be both fixed and rotating, and how it is that his V_1 is 180° out of phase with all the other fellows' V_1s and who is right? And can his diagram—or any of them—

The article ***"Vector Diagrams"*** *is continued on page 63*

Future of Broadcasting

Recommendations of the Beveridge Committee

The Report of the Broadcasting Committee, 1949, on which the future of British broadcasting will presumably be mainly shaped, was published after the normal pages of this issue had been arranged. We have accordingly inserted supplementary pages giving a summary of the most important recommendations, preceded by our comments on their implications

EVEN the severest critics of the Beveridge Committee's Report can hardly quarrel with it on grounds of superficiality. Within the 300-odd pages of the Report proper almost every aspect of the subject is surveyed in great detail, while the supplementary volume gives nearly 600 pages of evidence. The enormous amount of oral evidence heard by the Committee is not printed in full, though sometimes quoted in the text. It is clear that the Committee has made notable efforts to weigh and act upon all this evidence. The Report will remain as an enduring monument to their competence, patience and high principles. We shall be surprised if the recommendations are not accepted in essentials as the basis on which the B.B.C. Charter is ultimately renewed.

In matters of control and organization of broadcasting on medium and long waves there is no proposal for drastic changes in principle, though the detail alterations set out in the summary that follows are of some significance. The B.B.C. monopoly is to remain, and there is to be no advertising or sponsored programmes. In some respects the monopoly is to be strengthened and measures are proposed that are designed to increase the Corporation's independence of outside authority. Some important recommendations are intended as safeguards against "the undeniable dangers of monopoly." To many of us it is disappointing that the Committee has failed to meet the strong demand shown to exist in favour of introducing the competitive element into broadcasting on medium and long waves, though it is clear pleas for it were given due weight. It may be claimed that the vastly increased degree of self-government proposed for the Regional organizations may to some extent satisfy these demands. In our view, Regional autonomy does not inculcate competitiveness to any significant or valuable extent: listeners in one Region do not know whether programmes in another are better or worse than in their own.

Wireless World, in welcoming the Report as a whole, thinks the most important—and certainly the most technically interesting—parts are those dealing with e.h.f. broadcasting, which the Committee rightly considers should be developed as a matter of urgency. They even go so far as to say, if faced with the choice, they would assign to it a higher priority than television, at least so far as areas inadequately covered by the present sound service are concerned. Perhaps the most drastic recommendation of all is that public authorities and "approved organizations" such as universities should be licensed to set up and maintain e.h.f. local stations. These would be additional to those conducted by the B.B.C. True, this proposal is made with provisos and some diffidence, and carries the rather naïve clause that licences should be granted "after consultation with the B.B.C." We imagine no monopolist would willingly accept such an encroachment on his monopoly. Indeed, one gains the impression that here the Committee is hardly aware of the deep significance of its recommendation, or of the fact that it runs counter to many of the principles accepted elsewhere in their Report. Perhaps, however, their technical advisers have convinced them that medium- and low-frequency broadcasting constitutes inherently a natural monopoly, while higher frequencies become progressively less monopolistic!

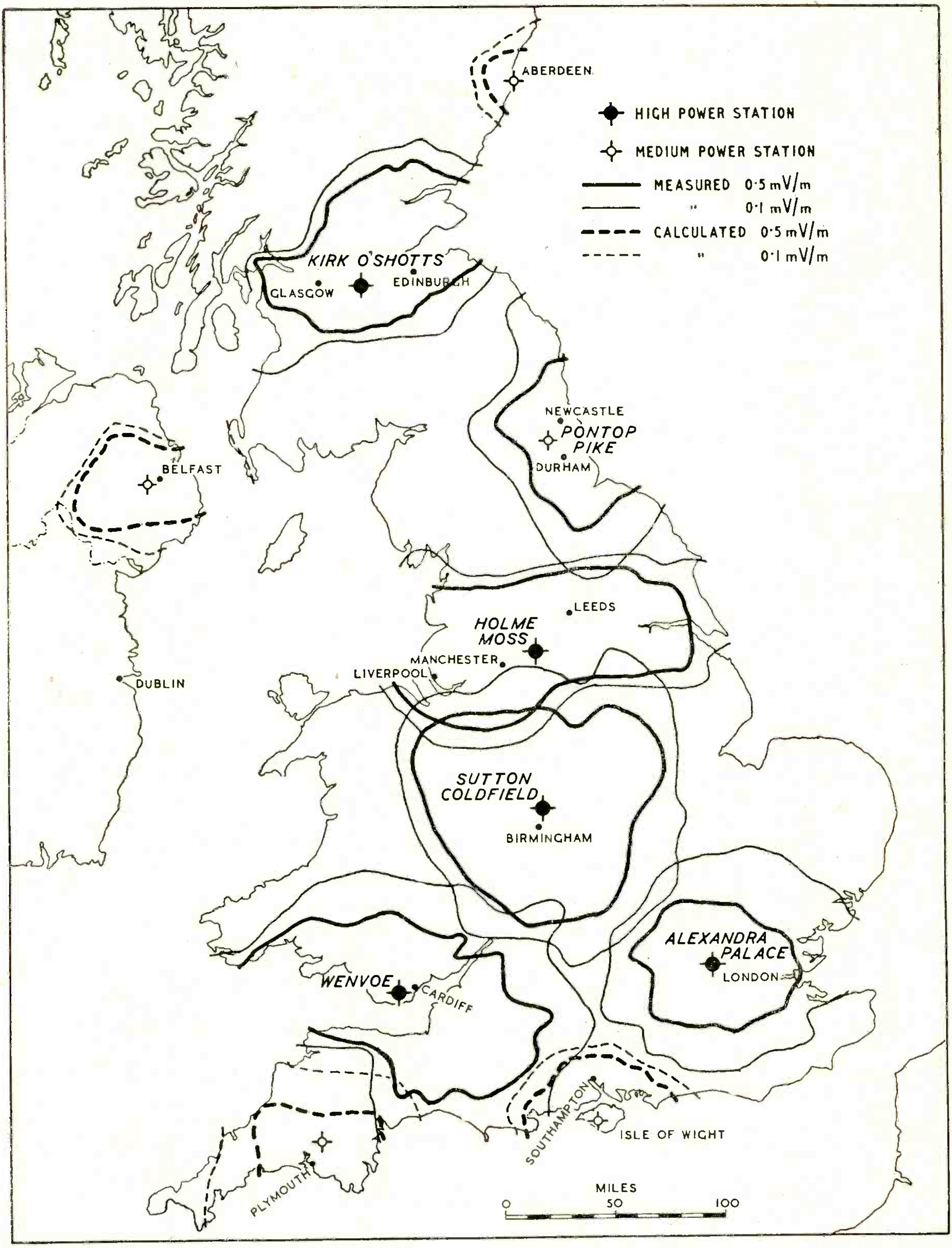
Though we foresee great opposition to this proposal, and also many difficulties in establishing a basis for licensing independent stations, the experiment is one that should be tried. It may have results that will be to the good of broadcasting, and ultimately to the benefit of radio as a whole. Many bodies would doubtless be willing to accept short term licences, without any guarantee of renewal after a period of, say, five years.

Summary of Recommendations

RADIOCOMMUNICATION in this country, is of course, prohibited except under licence from the Postmaster General, who so far has not granted more than one licence for broadcasting at any time. The first licence, granted to the British Broadcasting Company in 1922, was renewed in 1923 for two years, and in 1926, on the recommendation of a Government Committee of Inquiry, a Royal Charter of Incorporation was granted to the British Broadcasting Corporation for ten years.* This was renewed in substantially the same form in 1936, after another inquiry, for a further ten years. After deciding that "the present system of broadcasting is the one best suited to the circumstances of the United Kingdom," the Government, without recourse to an independent body, in 1946 renewed the Charter for a further five years. This Charter expires on December 31st and it will be recalled that the Lord President of the Council and the Postmaster General appointed jointly in 1949 a committee "To consider the constitution, control, finance and other general aspects of the sound and television broadcasting services of the United Kingdom (excluding those aspects of the overseas services

* The P.M.G.'s licence was still necessary.

B.B.C. TELEVISION PLAN



Existing and projected television stations and service areas as given in the Beveridge Report. The field-strength contours, some of which are derived from site tests, are for a receiving aerial 30 feet above ground level.

for which the B.B.C. is not responsible) and to advise on the conditions under which these services and wire broadcasting should be conducted after December 31st, 1951."

The Report of this Committee of eleven members, of which Lord Beveridge was chairman, has now been presented to Parliament and its recommendations will be debated in the House before a decision on the future of British broadcasting is made. In response to the invitation issued by the Committee, 223 memoranda were received from interested persons—either as individuals or groups—and numerous suggestions were received from members of the public. In accord with the practice of each of the previous Committees of Inquiry into Broadcasting—1923, 1925 and 1935—the sixty-two meetings of the full committee were held in private, as it was considered this contributed to greater freedom of discussion and frankness in expressing opinions. A large number of the memoranda submitted is published in a separate volume as an appendix to the Report.†

It is impossible, and, in fact, unnecessary in a technical journal, to deal with all the evidence and recommendations as so much is concerned with the organizational side of broadcasting. We propose, therefore, to limit our review of these two volumes to such evidence and recommendations as we consider are of direct interest to our readers, but not likely to be dealt with *in extenso* in the lay Press.

The fundamental recommendation of the Committee is that the B.B.C.'s monopoly should continue, that a new Charter, with modifications, should be granted for an indefinite period and that its work should be reviewed every five years by a small independent committee. There is, however, a reservation in the recommendation. It proposes that the Government should reserve the right to license "bodies . . . to conduct on specified conditions television for public showing" and to licence "public authorities or approved organizations to maintain and conduct local broadcasting stations."

The members of the Committee state that they felt it incumbent upon them to probe more deeply than their predecessors into the question of the monopoly of broadcasting, not only because of its importance but because, in contrast to the evidence given to the previous Committees of Inquiry, they found "a substantial body of serious opinion challenging monopoly itself." The Radio and Television Retailers' Association in its evidence attacked monopoly in principle and reported a poll of nine to one of its members in support of some form of commercial broadcasting alongside the present system.

On the organizational side it is proposed that the Charter should provide for the appointment by the Government—rather than the B.B.C.—of Broadcasting Commissions for the three National Regions, Scotland, Wales and Northern Ireland, with a view to giving them the greatest practicable measure of autonomy.

E.H.F. Broadcasting

Evidence on the question of e.h.f. broadcasting—both a.m. and f.m.—was given by, among others, the B.B.C., G.P.O. and Pye, and it is stated that the B.B.C. is ready to frame a practical scheme of development as a result of the tests made at Wrotham.

† "The Report of the Broadcasting Committee, 1949," 334 pp., H.M.S.O. price 6s 6d. Appendix H—Memoranda Submitted, 589 pp., H.M.S.O. price 10s 6d.

The Committee considers that the Government should regard the development of e.h.f. broadcasting as important and urgent both for securing better coverage for the present programmes and for increasing the diversity of programmes. It recommends that the terms of reference of the existing Television Advisory Committee should be enlarged to cover e.h.f. broadcasting as well as television. The plan now under consideration by the B.B.C. should, it is proposed, be revised to provide for the setting up of a number of local transmitters as an experiment.

Television

To support the evidence given by the B.B.C. on the extension of the television service a map, reproduced on the opposite page, is included in the Report. Although not relevant to the main consideration, it gives some interesting data. It is made known, for the first time, which stations will be sharing frequencies and, too, the site of the Newcastle station—on Pontop Pike, south-west of the town.

The stations and vision frequencies are:—

Channel 1 (45 Mc/s): Alexandra Palace and Belfast.
Channel 2 (51.75 Mc/s): Holme Moss and South Devon.
Channel 3 (56.75 Mc/s): Kirk O'Shotts and South Hants.
Channel 4 (61.75 Mc/s): Sutton Coldfield and Aberdeen.
Channel 5 (66.75 Mc/s): Wenvoe, Glam., and Pontop Pike.

It is pointed out that the Government should make it plain either in the new Charter or by some other means that it is prepared to issue licences for stations to transmit television for public showing in cinemas provided that the use of such frequencies as may be allocated does not interfere with the B.B.C.'s transmissions to the public in their homes and, too, that "spectacles and sporting events" are made available to both the home viewer and the public viewer.

On the question of financing the television service, which it is proposed should be distinct from the sound service both financially and administratively, it is suggested that the question of raising the television licence fee should be considered.

Wire Distribution

The Ullswater Committee of Inquiry (1935) recommended that the Post Office should undertake the unification and co-ordinated development of wire distribution in this country together with the ownership and operation of the relay exchanges. This was not adopted by the Government and the licensing of private concerns, which had been granted since 1927, was continued. When the present Charter of the B.B.C. was considered, prior to its renewal in 1946, the Government decided that a decision on the question of wire distribution should be deferred pending a review of the situation at a later date.

There appears to be no advantage in operating relays as a public service, and it is therefore recommended that a ten-year licence is granted in the first instance with power to take them over then or by two years' notice.

It is, however, recommended that where reception of B.B.C. transmissions is specially bad in sparsely populated areas and it would not be an economical proposition for a relay exchange to be operated as a profit-making concern, the B.B.C. might operate an exchange as an alternative method of serving the public. It is suggested that the B.B.C. should be asked to provide information on isolated areas of bad reception which could be served better by wire distribution than by broadcasting.

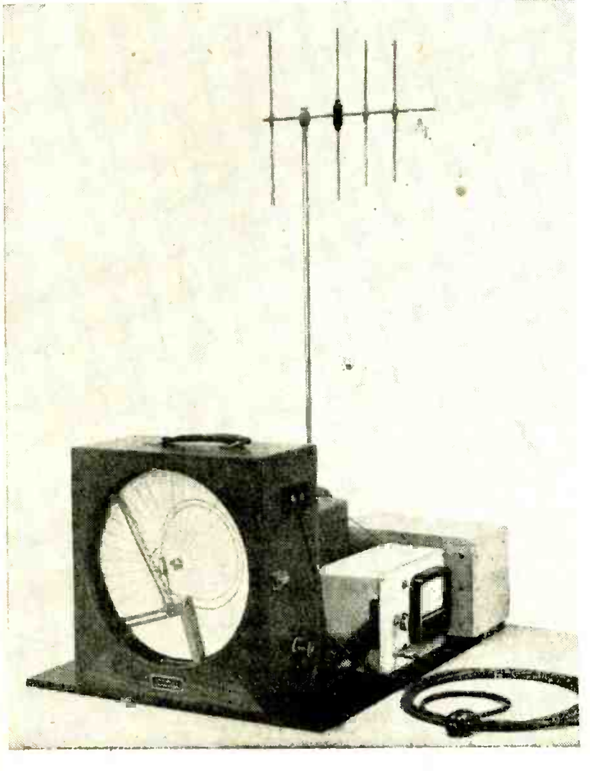
Polar Diagram Plotter

New Automatic Device for Saving Time in Aerial Design

DESIGNING television aerials naturally involves a certain amount of experimental work, and probably the most tedious part of this consists of taking polar diagrams. In a large multi-element array, for instance, it may be necessary to make as many as two hundred adjustments to the elements, with the same number of polar diagrams to show the results, before the characteristics of the aerial are satisfactory. By the ordinary method of taking readings and plotting these on polar-coordinate graph paper, each diagram takes about twenty minutes to complete, so one can see how much time has to be spent altogether on this unrewarding but necessary occupation.

It is therefore of some interest that Belling & Lee, Ltd., are now using in their laboratories an automatic apparatus that will trace a polar diagram in about fifteen seconds. A demonstration was given by the originator, F. R. W. Strafford, at a Television Society meeting on 11th January, and the system proves to be so delightfully simple that it provokes the immediate comment, "why didn't somebody think of this before?" The most straightforward method of plotting a polar diagram is to move a signal generator and radiator in a circle around the receiving aerial and take readings of signal strength at a number of positions. It is just as effective, however, and far more convenient, to keep the radiator fixed and rotate the receiving aerial about its own supporting mast, and this is the method used in the automatic plotter. As the aerial rotates, it drives a circular chart about its own axis at the same angular velocity. A pen recorder, energized by the output of the aerial and moving up and down a radius of the chart, then represents the signal strength at each point of the compass by the amplitude of its swing away from the chart axis. A small response from the aerial brings the pen towards the centre of the chart whilst a large response moves it towards the periphery, and so as the aerial and chart move round a continuous line is traced and the polar diagram is built up.

Automatic polar diagram plotter (not showing the local transmitter) with two comparative diagrams traced on polar-coordinate graph paper.



To do the work of recording on a circular chart in this way, Mr. Strafford has employed a slightly modified version of the Fielden "Servograph," described in the July, 1950, issue of *Wireless World*, page 244. Since this works on the servo principle and requires only a very small power input sufficient to deflect a moving-coil microammeter, the output from the aerial under test needs no amplification and, in fact, the receiver consists only of a germanium crystal rectifier as detector. The rotating chart of the "Servograph" is driven through a worm gear from the aerial mast, and the whole arrangement is turned by a geared-down electric motor. Apart from this external drive, the only other modification to the "Servograph" is that the recording pen is arranged to move across the chart in a true radius instead of describing an arc as in the standard instrument. This is necessary, of course, to give a truly representational polar diagram.

It will be noted from the illustration that the Yagi array under test is a miniature version. This has been scaled down to $\frac{1}{10}$th of the normal television dimensions so that it is convenient to handle whilst physical adjustments are being made to it—and, in fact, this is the normal Belling-Lee practice for designing aerials. The test frequency is, of course, increased ten times. When the design of the aerial has gone as far as possible with the miniature version, a full-scale model is built and final adjustments are made on this. It is understood that the automatic plotter is being adapted to work also with the full-sized aerials, although at the moment the ordinary methods of plotting are used.

The usefulness of the apparatus for quick comparative measurements was very well demonstrated at the Television Society meeting, when Mr. Strafford removed the director elements from the Yagi array one by one and showed the gradual reduction in directivity which resulted by a succession of polar diagrams on the same chart. The effect of reflections on the shape of the polar diagrams was also shown by an assistant who moved about between the radiator and the receiving aerial—an experiment which underlined the importance of doing this kind of work in an open space.

tell us which end of L is positive when the current is at 0° as shown ? If so, how ? And which way round the circuit is the current flowing during its positive half-cycle ?

The lack of a definite answer to the last question is because Mr. X omitted to draw an arrow in Fig. 3 to show it. But, you may say, this is an a.c. circuit, and the current goes both ways alternately, so why pick on one way more than the other ?

It is true that either way can be chosen ; but one reason for making a choice is that it may be necessary to specify the phase difference between this current and some other—say the current flowing in via the leads seen entering on the left of Fig. 3. Unless a direction is marked along each current path, the vector diagram cannot tell us whether they mean current flowing that way or the other. It is like referring a compass bearing to a map which has no arrow to show which is North. Another reason for marking the current direction is that it gives a clue to some of the other questions, about the voltages. Once we know which is the positive direction of the current, we can tell which end of a resistance is positive at the same time.

But even when the current arrow has been added to Fig. 3, the vector diagrams in Fig. 4 are not really clear and foolproof. One has to do quite a bit of working out to decide such questions as which end of L is positive at the start of the current cycle. And if the vector diagram doesn't save us this trouble, what good is it ?

Foolproof Diagrams

One of the shortcomings, as you may have guessed, is the voltage notation. Let us start afresh, using the double-subscript system (Fig. 5). The new diagram is simpler than the old, yet it is more precisely marked. It is much easier to refer to a point on it as, say " *c*," than as " the bottom of resistance R "—quite apart from the fact that in another diagram of the same circuit point *c* might be at the top end of R ! And we can refer to the voltage between any two points and state its direction. So now there should be no ambiguity ; at least, not if we say whether we are using the " rise " or " fall " convention for voltages.

But there are still several ways in which the vector diagram can be laid out. There is the " parallelogram " form, corresponding to Fig. 4(a), and the " triangle " (or, in a more complicated circuit, " polygon ") form, Fig. 4(b). And the voltages could be reckoned all clockwise (V_{ab}, V_{bc}, V_{ca}), or all anti-clockwise (V_{ac}, V_{cb}, V_{ba}), or some of each. Would this necessarily affect the directions of the vector arrows ?

It is rather difficult to discuss this, because all the different versions could be justified, according to the conventions preferred, and depending perhaps on the information given about the circuit and what has to be found. There is no room to go fully into all the possible alternatives and the reasons for them, so having duly noted that alternatives do exist, let us consider the reasons which have guided my own choice and led to a type of diagram which, so far as I know, is slightly novel, yet has substantial advantages over the usual sorts like those in Fig. 4.

The first thing to decide is whether a vector diagram is supposed to represent the voltage of one or more positions in the circuit relative to another, or the voltages round the circuit in a specified rotation.

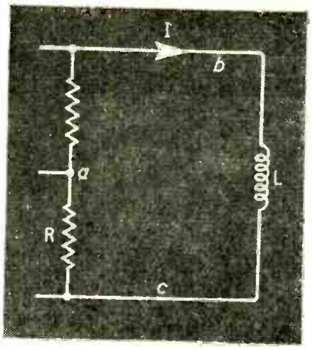


Fig. 5. The recommended version of Fig. 3.

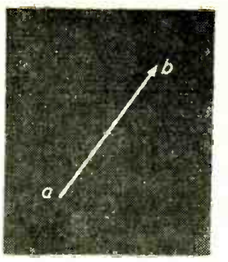


Fig. 6. Recommended method of showing the vector of V_{ab}

The latter seems to me less useful, because we know in advance that the total must always be zero, whereas it is generally useful to know—and usually by no means obvious—what are the relative potentials of different points in the circuit at various stages in the cycle.

Going back to our prototype vector, Fig. 2, we remember that the sinusoidally varying height of P above the horizontal through O represents an alternating voltage between two points, say *a* and *b*. We can regard this voltage either as the potential of *a* relative to *b*, or of *b* relative to *a*. Suppose it is the latter—*b* relative to *a*. In other words, *b* is regarded as having an alternating potential, relative to *a* at zero potential. It seems logical, therefore, to visualize the rotating end of the vector as representing point *b* in the circuit, and the end of the vector whose height above itself is always zero as representing the zero-potential point, *a*. This being so, we can label the ends of all the voltage vectors with the circuit points they represent, and there is then no need to label them with the voltages. The only question is whether our vector represents V_{ab} or V_{ba}.

That is a matter of choice or convention. In making the choice we can hardly help thinking about the arrow head attached to the vector. Actually, as we have seen, its purpose is to indicate the rotating end, and it has no necessary connection with the assumed direction of the voltage between the two circuit points. But it would be a distinct help if it could be made to correspond. Fig. 6 shows the labelling of the ends of a vector representing the voltage of a point *b* relative to a zero-potential point *a*. If you had to say whether this vector represented V_{ab} or V_{ba}, which would you choose ? Seeing that V_{ab} means the voltage in the direction *a* to *b*, could one reasonably choose V_{ba} ?

We still have to decide between the " rise " and " fall " conventions. Looking again at Fig. 6 for inspiration, we see that *b* is above *a*, representing a positive value of what we have (I hope !) decided to call V_{ab}. Does anybody seriously suggest that this should be taken to mean that *b* is negative with respect to *a* ? If not, then there is unanimous approval for the " rise " convention, by which V_{ab} means the change in potential on moving from *a* to *b*, so that a positive value of it means that *b* is more positive than *a*.

We have already simplified our vectors by rendering voltage labels unnecessary ; we can now simplify them further by omitting the arrow heads. They may

D

thereby forfeit their title " vector " ; but they never really had it, anyway, because the electrical engineers' rotating " vector " is not a vector in the strict mathematical sense. A simple straight line, of length proportional to the peak or r.m.s. voltage, with its ends lettered to correspond with the points in the circuit between which the voltage exists, represents that voltage in the neatest possible manner. It represents (in this case) both V_{ab} and V_{ba}. If you want to confine attention to one or the other, just put an arrow head on the appropriate end.

Showing Zero Potential

In most circuits one point is earthed, or at any rate is reckoned as zero potential. In the corresponding vector diagram, this would obviously have to be the fixed end of all the voltage vectors. Assuming *a* in Fig. 5 is earthed, we would have something like Fig. 7. The arrow heads mean that the point (*a*) from which they are directed is at zero potential, and that the whole diagram should be imagined as rotating anti-clockwise around it. The relative positions of the lettered points in the vector diagram meanwhile represent the changing potentials of the correspondingly lettered points in the circuit. It is obvious at a glance, for instance, that at the start of the current cycle (in the direction indicated by the arrow in Fig. 5) *b* is at its maximum positive potential relative to *c*.

But sometimes no particular point is earthed or zero, or perhaps there will be occasion to refer the voltages in turn to more than one point in the circuit. That is when the situation would best be represented by what I venture to call my generalized diagram, which for Fig. 5 would be as in Fig. 8. This surely reduces symbolism to its ultimate simplicity and economy of effort ; yet, for all that, it contains as much information as the orthodox vector diagrams, and, unlike them, is foolproof.

Attaching the current vector in the orthodox manner to any of the corners would single out that point for special attention, so to maintain the generality of the diagram I have shown it detached. Current being a different kind of thing from voltage, it is better not to represent it in a diagram as if it were of the same kind. The only excuse for attaching it, surely, is to make it easier for the eye to judge phase angles.

Directly any circuit point is taken as earthed, the arrow heads can be drawn in to proclaim that fact, and (if desired) the current vector attached ; and the diagram changes to the Fig. 7 style. Note the convention I have been using throughout for distinguishing the current, by a thicker arrow head than normal.

In some circuits the true zero potential point is actually none of those marked on it, and the situation is represented, say, by Fig. 8 rotating about some point inside or outside it.

The same type of diagram is applicable to any circuit network, however complicated. If there were, say, ten circuit points at the junctions of components, there would be 45 voltages in each direction between them, and labelling them all in the usual way, as in Fig. 3, would hardly enhance the clarity of the circuit diagram ! Nor could an orthodox type of vector diagram showing all of these voltages be unhesitatingly claimed as foolproof.

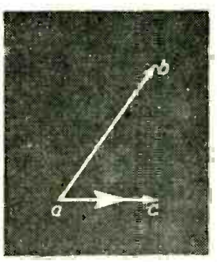


Fig. 7. Completed vector diagram for Fig. 5, assuming *a* earthed

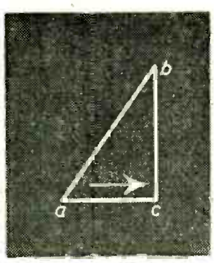
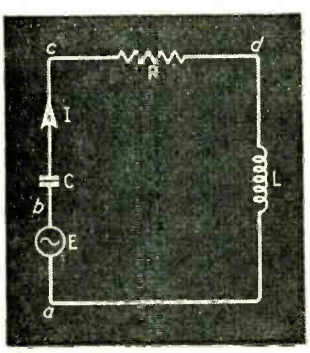


Fig. 8. Generalized form of diagram relating to Fig. 5.

Below : Fig. 9. Example of circuit diagram for practising the recommended method.



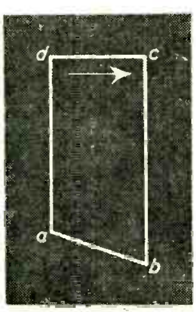


Fig. 10. Generalized diagram for Fig. 9.

How to Proceed

So far I have shown this type of diagram only for a purely series circuit, where there is only one current. But if the circuit includes parallel paths it is necessary to draw a current vector diagram, which in the general form would be separate from the voltage diagram but related to it. Just as the voltage diagram demonstrates Kirchhoff's Second Law, the current diagram demonstrates his First Law, about the sum of the currents arriving at (or leaving) any point being zero. Unfortunately the double-subscript notation doesn't work for currents, because all paths in parallel have the same terminal points. One can just number the currents I_1, I_2, etc.

I would like to show some examples of series/parallel circuits and their generalized vector diagrams, but unfortunately there is no room. However, some simple examples will, I hope, occur next month when we consider valve circuits. In the meantime here is a summary of the procedure I recommend, applied to the series circuit shown as Fig. 9. The object is to find the phase angle between E and I, and the circuit impedance (E/I), given the component values.

(1) Letter the junctions in the circuit diagram *a*, *b*, etc., and

(2) Mark an arbitrary direction of current.

(3) Draw a vector in an arbitrary direction (normally " 3 o'clock ") to represent a r.m.s. current of 1 amp.

(4) The voltage tending to drive current through R in the direction of the arrow is V_{dc} (the " long way round " the circuit), so represent it by a line *dc* in the same direction as the I vector, and of a length corresponding to IR volts (which is numerically

equal to R ohms). (In the direction *cd*, opposite to the I vector, this line represents the current-opposing voltage).

(5) The voltage tending to drive current through L is V_{ad}. Draw a line *ad* representing it $= IX_L =$ (in this case) $X_L = 2\pi fL$ ohms, so that the I vector lags it by 90°.

(6) Similarly draw *cb* of length proportional to $1/2\pi fC$ ohms, so that the I vector leads it by 90°.

(7) Then the length of the line *ab* represents to the same scale the net impedance of the circuit and (as I = 1 amp.) the e.m.f. E; and its direction relative to the I vector shows its phase difference. In this case, with the frequency slightly lower than the resonant frequency, so that the reactance of C is greater than that of L, I is seen to lead E. By turning the diagram round anticlockwise we can see how the potentials of all the points vary with respect to one another in relation to the cycle of current. We can also easily see, with this type of diagram, how varying the component values would affect the various voltages and phases.

Thermal Soldering Shunt

Protecting Components Against Excessive Temperature Rise

By P. F. DUNCAN

IN an article entitled "Modern Soft-soldering Technique" in the June, 1950, issue of *Wireless World* a warning was given of the risk of damaging or ruining components by the use of an insufficiently hot soldering iron, the iron having to be applied to the joint for an appreciable time results in the component becoming badly overheated.

The probability of damage during soldering, however, is much more general than that, especially with miniature components. For example, if a miniature carbon composition resistor is soldered into circuit *with an iron at correct temperature* the rated resistance value will change by more than 20 per cent, i.e., by more than the manufacturer's widest tolerance, unless at least ½in of wire termination is left between the body of the resistor and the soldered joint. In many equipments which incorporate miniature components space is at a premium and the miniature resistor will often be found with its wire ends cut so that the distance between body and joint is little more than the length of the body—certainly less than the safe distance of ½in.

Now the normal working temperature of a soldering iron is not much below 400° C at the optimum voltage and as the difference in thermal capacity between a soldering iron and a resistor is very great the result is that the resistor quickly attains the temperature of the soldering iron, if the bit is applied close to the resistor body.

This undesirable state of affairs has already been investigated at the Telecommunication Research Establishment, Ministry of Supply, where experiments have been made on the resistance/temperature characteristics of several types of resistor. The conclusion reached was that if large and permanent changes in resistance value are to be avoided the temperature rise of the resistor must not exceed 100° C; preferably it should not exceed 50° C.

Fortunately, there is a very simple method suggested by T.R.E. for avoiding heat conduction between iron and component. The method works on exactly the same principle as that applied when a heavy current is to be passed to a sensitive meter—the excess is dissipated in a shunt. A thermal shunt for use when soldering must have a thermal capacity considerably greater than that of the component which it is to protect; to dissipate the unwanted heat it must have a large surface of freely radiating material.

A shunt somewhat of this nature will be found ready to hand in the tool kit of everyone who is likely to be concerned with soldering joints in radio equipment—it is nothing more than a pair of long-nosed steel pliers. All that is necessary to obtain a reasonable measure of protection when soldering small components into circuit is to use the pliers to hold the component by its terminating wire, applying the pliers between the body of the component and the joint, and to continue so to hold the component for at least 15 seconds after the joint has been made. Provided the pliers are applied as close as possible to, but not touching, the body of a resistor, the distance between soldering iron and resistor will be about ⅜in (the width of the pliers). With a RMA16 resistor this will result in a change of resistance value of about 2½ per cent as against a change of some 25 per cent without the pliers. The use of the pliers is equivalent to increasing the length of terminating wire to ½in.

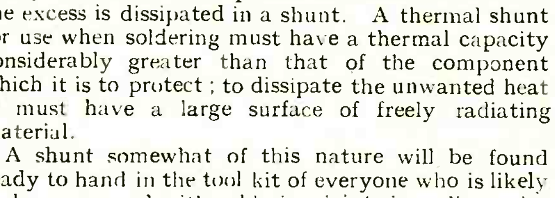


Fig. 1. Crocodile clip with two copper jaws sweated on as shown here makes an ideal thermal shunt.

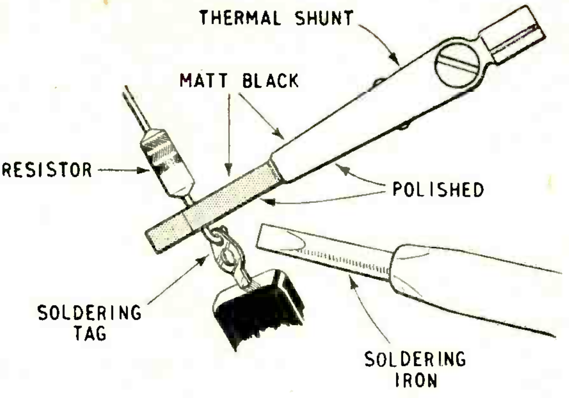


Fig. 2. When soldering a resistor to a soldering tag the jaws of the thermal shunt must not be in contact with both the tag and the component.

Although this use of steel pliers as a thermal shunt will be found to be reasonably satisfactory for general work, the pliers do not fully meet the requirements of a really effective shunt. The component will still be subject to a temperature rise which in the case of a miniature resistor may make it susceptible to damage later under full-load conditions.

A more useful thermal shunt, and one which is easy to make, was therefore suggested by T.R.E. It consists of an ordinary crocodile clip with its jaws loaded by sweating on a pair of copper bars measuring about $\frac{1}{8}$in thick by $\frac{1}{4}$in wide by $1\frac{1}{2}$in long, as shown in Fig. 1. This provides a shunt of good conductivity and high thermal capacity. Perhaps even more important, it will remain in position on the terminating wire after the soldering is done until it is removed by hand, whereas, with the pliers, the tendency is to remove the pliers at the same time as the soldering iron.

The use of this improved shunt reduces temperature rise in miniature resistors to about a quarter of that with no shunt, i.e., to within the safe limit of 100° C. Moreover, with the copper-loaded clip the time during which the soldering is applied is not critical. If the joint is soldered within ten seconds there will be less than 1 per cent permanent change in resistance value of a miniature resistor.

The heat absorbed in the shunt is dissipated by convection and radiation. It is therefore an advantage to polish one side surface of the shunt and paint the opposite side surface matt black. If the polished side is placed next to the joint, radiation transfer from the iron will be reduced; the matt next to the component will have a better radiation property. The shunt should obviously be allowed to cool if it has become heated through frequent use.

If the joint is made with a soldering tag, it is important to ensure that the shunt is not actually in contact with both the tag and the component. If it is, here will be a low impedance heat-conducting path —just the opposite of what is required. A space of 1/16in on each side of the shunt will avoid this undesirable effect (see Fig. 2).

Finally, remember that all the good effects of a thermal shunt will be nullified if the component has already been damaged when tinning its wire ends. So use the thermal shunt when you tin the connection wires.

BOOKS RECEIVED

Questions and Answers on Radio and Television. By E. Molloy (Fourth Edition). Over four hundred questions covering all aspects of radio and television transmission and reception; intended to be complementary to existing text books. Pp. 138 + xx; Figs. 64. George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 5s.

Methuen's Monographs on Physical Subjects. **Semi-Conductors.** By D. A. Wright, M.Sc., F.R.A.S., F.Inst.P. Elementary account of the properties of semi-conductors; the theory of electron flow in them and across the boundary between them and either a metal or a vacuum. Pp. 128 + x; Figs. 32. **Photons and Electrons.** By K. H. Spring, M.Sc. Brief account of the main ways in which electrons interact with radiation, laying particular emphasis on phenomena associated with high energies. Pp. 100 + xvi; Figs. 38. **An Introduction to Servo-Mechanisms.** By A. Porter, M.Sc., Ph.D. Explains what servo-mechanisms are and indicates in terms of elementary examples the theoretical foundations of the subject, with particular emphasis on the basic problems of servo design. Pp. 150 + xii; Figs. 70. Methuen & Co., Ltd., 36, Essex Street, London, W.C.2. Price 7s 6d each.

Adventure in Vision. By John Swift. Overall story of television during its first quarter of a century, written for the layman. Pp. 195 + xxx; diagrams and 32 plates. John Lehmann, Ltd., 6, Henrietta Street, London, W.C.2. Price 15s.

The Electronic Photographic Speedlamp. By John Harrison. Practical description of every aspect of a new photographic aid, including how to make it and how to use it. Pp. 52 + xvi; Figs. 23 and 4 plates. Bernards (Publishers), Ltd., The Grampians, Western Gate, London, W.6. Price 3s 6d.

Microwave Electronics. By John C. Slater, Ph.D. Mathematical approach to the fundamental theory of the subject as a branch of theoretical physics, with application to the klystron, linear accelerator, cyclotron, magnetron, etc. Pp. 391 + xxix; Figs. 91. Macmillan & Co., Ltd. (agents for D. Van Nostrand Co., Inc.), St. Martin's Street, London, W.C.2. Price 45s.

Traité de Radioguidage. By S. Ostrovidow. General principles of the various radio aids to navigation; gives broad descriptions of systems rather than fundamental theory or special applications. Pp. 189 + xli; Figs. 134. Editions Chiron, 40, Rue de Seine, Paris, 6.

Cours Complet pour la Formation Technique des Radios Militaires et Civils. By Georges Giniaux (Third Edition). Technical instruction or handbook for radio operators, giving fundamental theory and practical descriptions of radio apparatus. Pp. 538 + xix; Figs. 328. Editions Chiron, 40, Rue de Seine, Paris, 6.

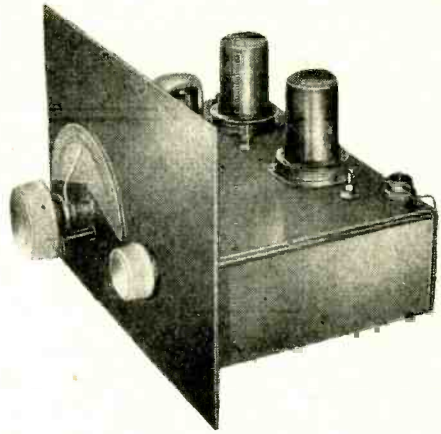
Atoms and Atomic Energy. By R. W. Hallows, T.D., M.A.Cantab., M.I.E.E. History of research and explanations in simple language. Pp. 172 + xxxvi; Figs. 27 and 8 plates. Chapman & Hall, Ltd., 37, Essex Street, London, W.C.2. Price 10s 6d.

Newnes Short-Wave Manual. Edited by F. J. Camm. Design, construction, operation and adjustment of short- and extra-short-wave receivers, aerials and associated equipment, with designs for seven receivers. Pp. 166 + xxxiv; Figs. 100. George Newnes, Ltd., Tower House, Southampton Street, Strand, W.C.2. Price 6s.

More About

Band-pass Converters

Extending Receiver Coverage to Below 200 Meters



By H. B. DENT

THERE is an interesting part of the radio spectrum very often ignored by short-wave listeners and that is the portion which lies between 100 and 200 metres. It is not covered by the ordinary broadcast receiver and few of the so-called all-wave sets take it in either. Most of the communications receivers do, however, but curiously enough most types of the popular R1155 have a gap in the tuning range here. The actual gap is 1.5 to 3.0 Mc/s, or 200 to 100 metres.

It was with the idea of filling in part at least of this gap that the 160-metre converter described here, and first mentioned in the previous article dealing with a 10-metre converter for the R1155 receiver (October issue, pp. 373 to 375), was built.

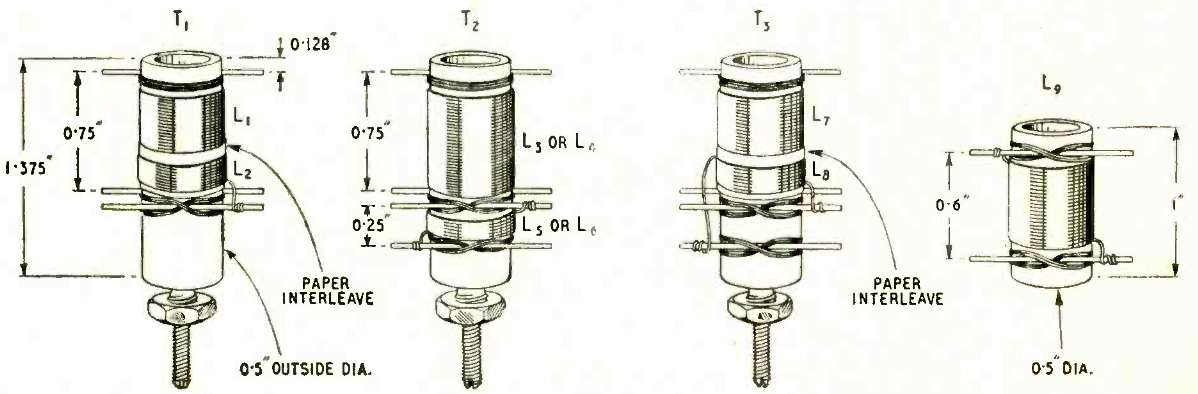
The region between 100 and 200 metres has quite a lot to offer the short-wave listener and it rarely gets any publicity. Parts of it are used by coastwise shipping for passing routine messages from ship to shore and from ship to ship, sea-going trawlers use it, so do lightships, radio telephony being the prevailing medium. It is shared also by amateurs on 150 to 175 metres, and there is now some broadcasting, which appears to be reasonably clear of interference, between 185 and 200 metres, and also in the region of 120 metres. This 160-metre conver-

COIL TABLE FOR 160m CONVERTER

	Coils	Wire s.w.g.	Turns	Winding Length	Remarks
T_1	L_1	No. 28 En	12	0.2in	Wound over "earthy" end of L_2, paper insulation.
	L_2	No. 38 En	90	0.7in	Close-wound single layer.
T_2	L_3	No. 38 En	90	0.7in	Close-wound single layer.
	L_5	No. 28 En	12	0.2in	Wound earthy end of L_3, on former, not overwound.
	L_4	same as L_3	—	—	—
	L_6	same as L_5	—	—	—
T_3	L_7	No. 28 En	35	0.7in	Close-wound single layer.
	L_8	No. 28 En	7	0.2in	Wound over h.t. end of L_7, paper insulation.
	L_9	No. 30 En	33	0.5in	Close-wound single layer.

T_1, T_2 and T_3 are wound on Denco 0.5 in diameter "Maxi Q" polystyrene formers. L_9 is wound on a 0.5 in diameter bakelized paper former 1in long

Details of the formers and position of the windings for the r.f. and i.f. transformers T_1, T_2 and T_3, also of the oscillator coil L_9 in the 160-metre converter.



ter covers just about 1 Mc/s and so takes in the 1.5- to 2.5-Mc/s part of the region only.

The main reasons for restricting its range is that pre-tuned wide-band signal circuits, as in the 10-metre model, are employed and there was a definite limitation imposed on the inductance of the coils by the need to keep the size as small as possible, within reasonable limits, and use a design which could be reproduced without too much difficulty with simple tools. Wave-winding was, of course, out of the question, but by using the Denco "Maxi-Q" ½-in diameter formers it was found possible to get about 170 μH of inductance in just under ¾ in of winding if No. 38 s.w.g. enamelled wire was used. The gauge is rather fine for a solenoid winding but it can be done with a little patience and, if needs be, by winding under a low-power magnifying glass.

With 170 μH padding capacitors of 50 pF will ensure tuning to the mid-point of the 1.5- to 2.5-Mc/s band and give a fair latitude in the adjustment of the dust core. But, with 50 pF capacitance and using coupled circuits in the r.f. stage,* damping resistors of 3.8 to 4 kΩ would have to be used to give the desired band width and the gain of the r.f. stage would be about 12 times only with a valve such as the EF50.

Although not unreasonable for a single stage a little more would not be unwelcome, so a compromise was made and the damping resistors raised to 10 kΩ, the band-pass circuits slightly over-coupled and staggered in tuning. No measurements of actual gain have so far been made, but the performance is quite satisfactory and the achieved r.f. gain seems to be rather better than the calculated figure just quoted.

As regards the actual design and construction of the 160-metres converter it will suffice to say that it follows closely on that of the 10-metre model; the chassis is the same size and shape, the circuit is the same except that permeability tuning replaces capacitance tuning in the r.f. and i.f. circuits but the arrangement of the coils is slightly different.

These differences are all brought about by the already-mentioned forced change in the design of the coils, but variable padding capacitors, in conjunction with fixed dust iron cores, will produce sensibly the same results. The Cyldon 30-pF variable trimmer, used for the i.f. circuit in the 10-metre model, could be employed in the 160-metre unit with say 20 to 30 pF fixed capacitors in parallel for the r.f. stages, but without the additional fixed capacitance for the 6-Mc/s i.f. output transformer.

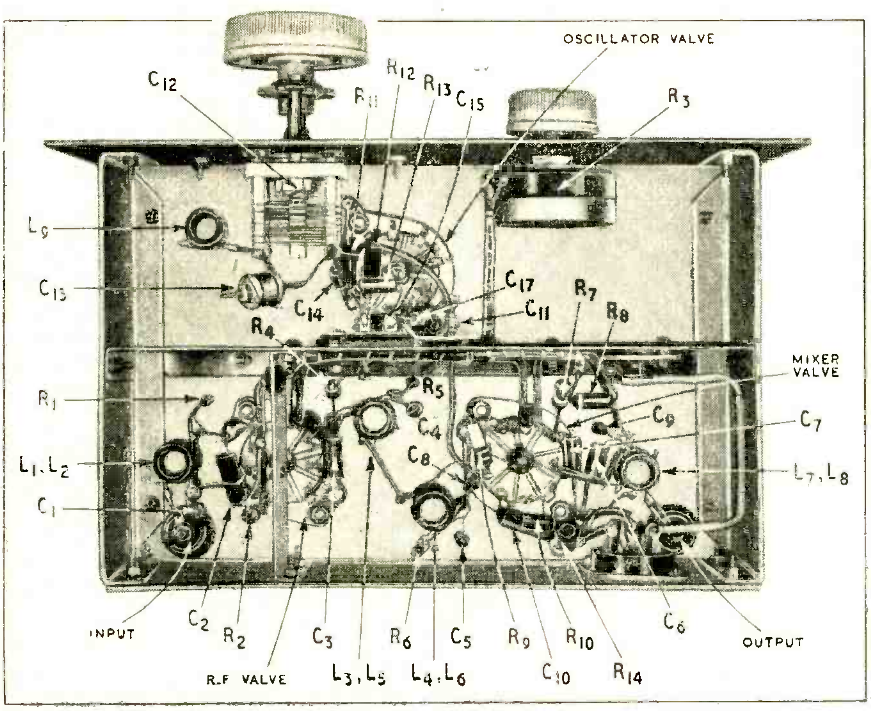
The few changes enumerated necessitated another slight modification in the circuit, which is that link coupling is employed for the r.f. band-pass circuits in place of mutual inductance coupling. The two coils are not individually screened so that there is a little mutual coupling but it is insufficient without the link windings.

A few very minor modifications in component values have been necessitated by the lower signal frequency, one is that all by-pass capacitors are 0.01 μF capacitance and the oscillator variable capacitor is increased to 25+25 pF. A pattern with staggered sets of vanes as distinct from the butterfly type was chosen in order to extend the length of the tuning scale. The butterfly pattern has a 90° coverage whereas the staggered-vane type swings through 180°. Although the actual frequency coverage is smaller in the 160-metre model than in the 10-metre one —1 Mc/s compared with 2 Mc/s— the former caters for a somewhat larger population of signals so that a longer scale is an advantage.

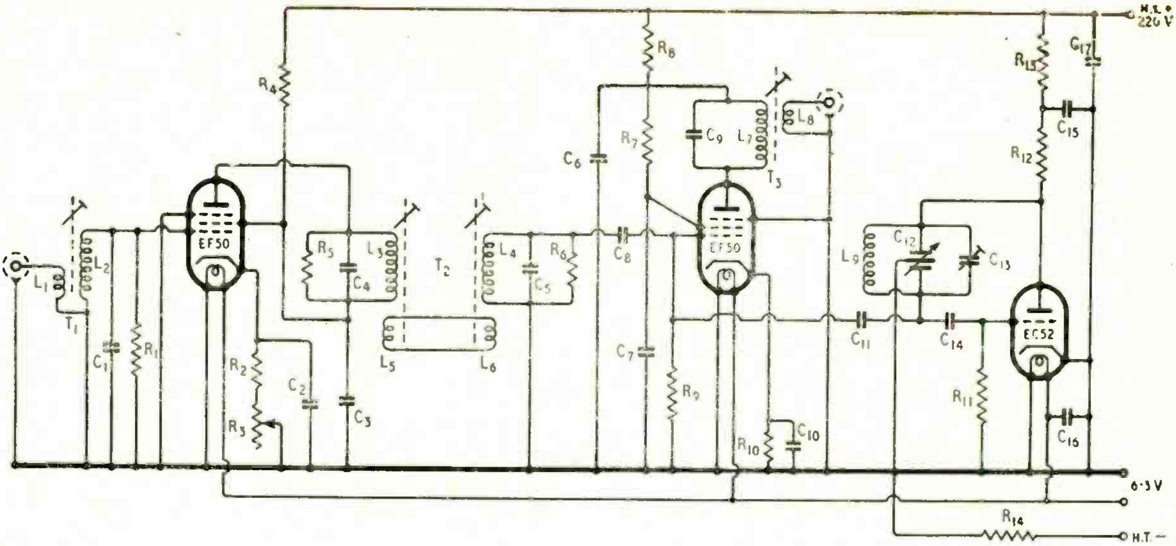
The actual make of components is relatively unimportant as the highest frequency reached is 8.5 Mc/s only and that is in the oscillator circuit. Tubular paper by-pass capacitors appear quite satisfactory, but physically small ones were chosen, as while there is no overcrowding of parts, space is not unlimited. In most positions a 20-per cent tolerance is acceptable, but exceptions may have to be made for C_1, C_4, C_5 and C_9, which should be selected to be within ±10 per cent at the outside of the required capacitance.

Valves are quite important in a unit of this kind having wide-band couplings and while the EF50

* Design Data No. 4—Wide band Amplifiers *Wireless World* May 1946 pp. 161-162.



Under-chassis view of the 160-metre converter. The main differences between this and the 10-metre model is in the positions of the various coils and transformers and in the capacitance of the r.f. by-pass capacitors.



Theoretical circuit of the 160-metre converter. Component values are as follows. Capacitors :—C_1, C_4, C_5 = 50pF ; C_2, C_3, C_6, C_7, C_{10}, C_{15}, C_{16}, C_{17} = 0.01μF; C_8 = 100pF ; C_9, C_{14} = 22pF ; C_{11} = 5pF ; C_{12} = 25 + 25pF variable; C_{13} = 3 − 30pF (air trimmer). Resistors :—R_1, R_5, R_6, = 10 kΩ (¼W), R_2 = 150Ω ; R_3 = 10kΩ (3W) variable ; R_4, R_8, R_{13}, R_{14} = 2.2kΩ; R_7 = 68kΩ ; R_9 = 2.2 MΩ ; R_{10} = 470Ω ; R_{11} = 15kΩ ; R_{12} = 33kΩ (1W). All capacitors 350V d.c. wkg. and resistors ½ W except where stated.

was chosen for the r.f. and mixer stages, more up-to-date miniatures could be substituted with no appreciable effect on performance. But the substituted valve must have a similar mutual conductance, or better. The oscillator is an EC52, but again a high-g_m triode could replace it, or an r.f. pentode, triode-connected, would serve just as well. Anode, screen and suppressor would be strapped to form the triode anode. The valve capacitances will be higher than in the EC52 but the Colpitts circuit somewhat offsets the increase in inter-electrode capacitance as the tuned circuit is joined across the anode and the grid of the valve so that the anode-cathode and grid-cathode capacitances are in series across the circuit.

The "stagger" in the tuning of the circuits was not based on theoretical considerations but was determined by trial. It was found that if L_2 is tuned to 2,000 kc/s, L_3 to 2,200 kc/s and L_4 to 1,800 kc/s the response is reasonably uniform over the larger part of the waveband. Other combinations would very likely give a similar performance.

The full oscillator coverage, determined by an Eddystone absorption wavemeter, is 7.45 to 8.55 Mc/s using the 25+25 pF capacitor. The calculated inductance of the oscillator coil is 11.5 μH.

The resistor R14 is required only when the converter is used with the R1155 receiver. Its purpose was explained fully in the description of the 10-metre unit.

TELEVISION "FIRE HAZARD"

IN the January issue of *Wireless World* we drew attention to points in the design of domestic radio equipment which tend to reduce the risk of shock and, more especially, fire. Since that issue went to press, we have seen the current *F.P.A. Journal*, which features the alleged "fire hazard" due to television sets in particular. We give below, without comment, a few extracts from the journal, which is the organ of the Fire Protection Association. Most emphasis is on dangers in the mains supply.

"A television set may be considered as constituting a greater fire risk than a radio set on account of higher voltage and heavier current rating. There is also greater heat from a television set, which necessitates particular care to ensure that the provision for ventilation is not obstructed. Television sets should not be left unattended whilst operating."

"All plugs should be switch controlled and, if the switches are single-pole, the connection should be tested by a competent engineer after installation to ensure that the switch is on the 'line' and not on the 'neutral.'"

"The object of these notes is to stress the importance of remembering that, when radio sets, and particularly television sets, are not in use they should be disconnected from the supply either by a double-pole switch, or by withdrawing the plug if working from a socket-outlet without switch control, or one controlled by a single-pole switch."

"In all instances where it is not known definitely that the supply is controlled by a double-pole switch, a wise precaution would be always to withdraw the plug from the socket-outlet when the set is not required."

E.H.T. from an R.F. Oscillator

Simple Supply Unit for Electrostatic C.R. Tubes

By C. J. DICKINSON, B.A., B.Sc.

MUCH attention has been given recently to the generation of extra-high tension supplies for cathode-ray tubes by means of high-frequency power oscillators. The use of the method is still almost entirely confined to magnetically-deflected tubes, where the voltage required is high and where the current drain is small. Curiously enough, the oscillator method has not yet found favour for electrostatic-tube supply, although it has several distinct advantages over the more conventional transformer and half-wave rectifier. The average electrostatic cathode-ray tube used for test or research purposes has a screen diameter not larger than 6in—usually rather smaller, in fact. Nearly all tubes of this size can be operated with good brightness and focus from a supply voltage of 2 kV or less; and unless there are severe electrostatic fields in the vicinity of the tube and supply network, a current through the potentiometer chain of 1 mA is generally considered adequate. At the expense of a current drain of 20-40 mA from a 350-volt positive supply (which probably exists to run associated equipment) an e.h.t. supply can be produced without any of the trouble and expense of e.h.t. mains transformers.

The advantages of such a supply are very considerable, and are not always completely realized.

1. The cost is small: the whole supply unit consists only of a small power valve of almost any type, an oscillator coil which can be wound without great difficulty, a rectifier and suitable smoothing.

2. Very little smoothing is required. For example, a π-filter as illustrated in Fig. 1 (using a total of 0.002 μF) will reduce the h.f. ripple to less than 1 volt peak-to-peak under average conditions. The equivalent ripple from a mains derived supply is generally at least 5 volts peak-to-peak.

3. The shock from an r.f. supply can never be very dangerous, since the oscillator will be stopped at once by even a slight extra load.

4. It is very easy to control the voltage output of an oscillator supply by controls fitted to comparatively low-voltage circuits. Tube sensitivity can thus be altered very readily.

5. The complete unit is small and compact.

6. The circuit provides automatic delay for the application of e.h.t. to the cathode-ray tube, thereby allowing the cathode to be pre-heated. Since most e.h.t. valve rectifiers are directly heated, and since metal rectifiers also conduct at once, this is often a source of trouble with mains-derived supplies.

7. There is very little difficulty in removing residual grid/cathode ripple. A decoupling capacitor of 0.01 μF between the two electrodes should eliminate brightness modulation completely without slowing up the operation of the brightness control appreciably.

8. A negative supply, such as is ordinarily used for electrostatic tubes, does not need a valve rectifier whose heater is at a high potential to earth. There is thus no necessity for a low-voltage winding to be provided on the oscillator coil.

Against these very considerable advantages, there are only two real disadvantages. One is that the tube heater has still to be operated from a well-insulated supply. The other is that the high-frequency oscillation can "leak" into other parts of the equipment—through electrostatic or magnetic pick-up, or via the high-tension supply. However, most people would prefer the job of removing interference at 50 kc/s than at 50 c/s. The interference field from the e.h.t. winding of a mains transformer, or from its associated circuits, is very much more troublesome (in the author's experience) than any amount of h.f. can be. The reactance of a 1 μF capacitor is only a few ohms at 50 kc/s, and decoupling is simple and cheap.

Probably the majority of electronic enthusiasts who have never given more than passing consideration to an oscillator supply for their portable oscilloscope, for example, would explain their

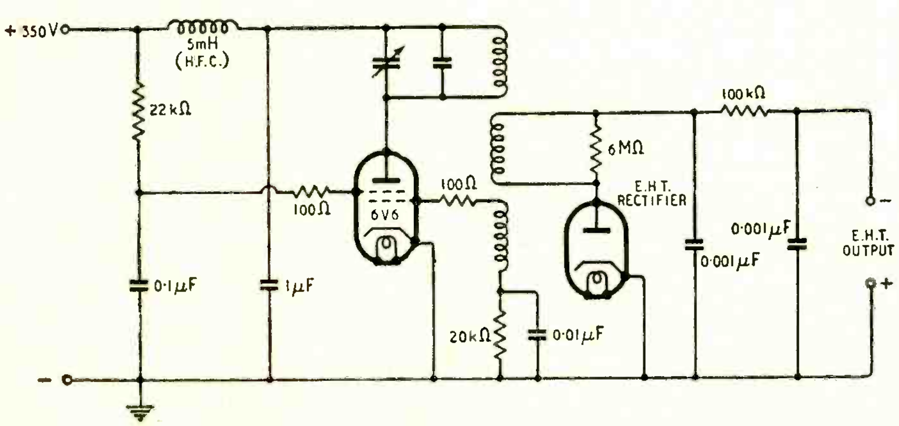


Fig. 1. Circuit diagram for a simple e.h.t. negative supply unit, using an r.f. oscillator.

conservatism by the constructional difficulties of the coil. A complete r.f. transformer can be bought for about 30s. (a suitable design would be the Hazlehurst C17/50) but for those less well endowed a comparatively simple model can be built at almost negligible expense, and with very little trouble.

The efficiency of even a home-made power unit of this sort can be as high as 20 per cent; and simple calculation shows that an input of 30 mA at 350 volts should be perfectly adequate to give 1 mA at 2,000 volts. Those who are more ambitious may attempt to run the heater of the cathode-ray tube itself from the oscillator. The extra drain of 4 volts at 1 amp is considerable, and a total h.t. current drain of 60-80 mA must be allowed for. Although this will necessitate a larger power valve (e.g., a 6L6, KT66, or 807) the same coil may be used—and many might well consider this a small price to pay to be able to dispense entirely with mains transformers for the e.h.t. circuit.

A suitable circuit for producing 2,000 volts at 1 mA, or a greater current at a lower voltage, is shown in Fig. 1. The exact frequency is relatively unimportant, though it is preferable for it to be outside the audible range. Any frequency between 20 and 100 kc/s may be used. In practice it is simpler to build the transformer first, and then adjust the whole oscillator to its most efficient working frequency. The circuit will produce very little oscillation interference on a normal h.t. line; and if it is desirable to keep even a trace out of the time base or amplifiers the simplest remedy is to tap off the power supply to the oscillator *before* the h.t. smoothing choke, as illustrated in Fig. 2. This choke will effectively block all r.f., and the method does not introduce appreciable 50-c/s amplitude modulation. Other types of radiated interference may be minimized by building the circuit well back in the chassis, with the coil underneath if possible. It is very unlikely that it will have to be further screened.

It is very important that a load should be maintained across the output, since the voltage may otherwise rise to a value which might cause damage to coil

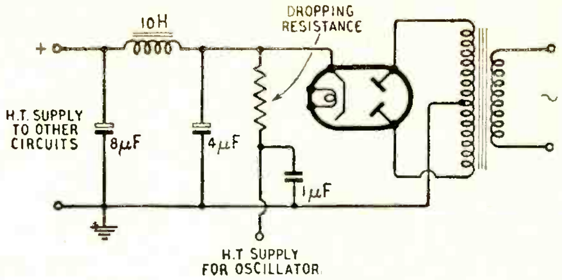
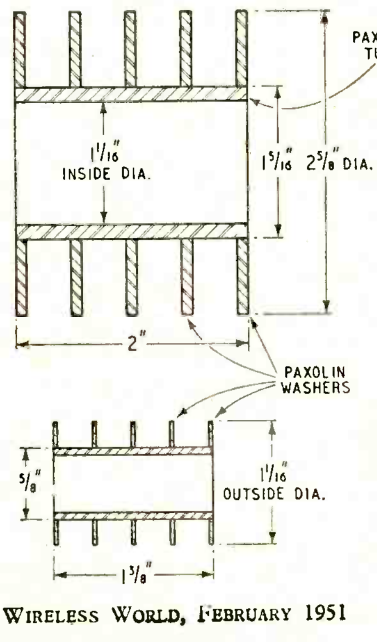


Fig. 2. Method of supplying the high tension to an r.f. oscillator to produce the minimum interference on the h.t. line.

or capacitors. In addition to the potentiometer network, it is therefore advisable to put a high value resistance directly across the winding, in case of a failure of the rectifier valve. Voltage control may be achieved either by altering the value of a series resistance in the power supply, or by de-tuning the anode circuit. The former method is more economical. The circuit will only function with the anode circuit coupled to the grid in the right phase. If the circuit does not oscillate immediately, the effect of reversing the grid coil connections should be tried.

When the whole circuit is assembled a load consisting of a milliammeter in series with a 2-megohm resistor should be coupled to the output. The anode circuit may now be tuned by observing the e.h.t. output voltage, and a check should be made to ensure that the cathode current of the oscillator valve is less than its rated maximum (50 mA for a 6V6). The capacitance required across the anode coil will be about 0.001 μF, but this value will have to be adjusted to any specific coil design.

Fig. 3 shows the essential constructional details of the transformer. Gauge 36 s.w.g. double cotton-covered wire is used throughout, and no exact number of turns is specified. If the wire is wound fairly evenly across the channels up to just short of the top—using the dimensions indicated—the ratios will be correct enough. A very considerable latitude of design is permissible. The inner coil former can probably easily be obtained, and its thickness is unimportant. The outer paxolin former can probably be found somewhere in the junk box; but if not, a short length of thick, wide-bore glass tube could be used instead. It is most important to see that the whole transformer is constructed with every care about insulation, since the electrical stresses may be very great.



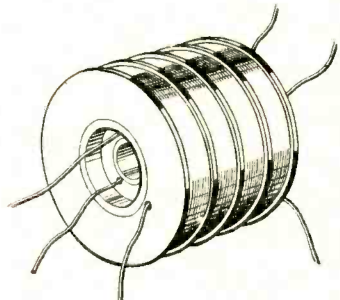


Fig. 3. Details of coil construction. All channels should be filled nearly to the top of the insulating washers with gauge No. 36 s.w.g. (0.0076 in dia) d.c.c. wire.

When the formers have been obtained, and cut to length, the paxolin washers should be cut or turned from sheet. Five washers are required for each coil. The washers for the outer coil should be $\frac{3}{32}$in thick, and those for the inner coil $\frac{1}{32}$in thick. The outside and inside diameters are evident from the diagram. It assists in the winding of the outer coil if a thin radial slot is cut on one face of three of the washers, to let the wire be taken from the top of one "pie" to the bottom of the next. When the washers have been glued in position, small holes for threading the wire should be drilled in the inner former for the grid and anode windings, and through the two end washers for the external e.h.t. windings. A central metal bolt must not be used for fixing the coil, as this will greatly reduce the efficiency of the transformer.

The grid-circuit coil occupies one complete channel of the inner coil former, and the anode coil is wound consecutively in the remaining three channels. The ratio of turns in the anode and grid circuits is therefore about 3:1. In winding the anode coil, the wire should be led from the top of one channel to the bottom of the next through some thin insulating sleeving which will not interfere too much with the winding. For the outer coil the wire is led to the bottom of a channel down the narrow radial slot previously cut in the side of the washer. It is then waxed into position before the next winding is begun.

Paraffin wax should be melted with a soldering iron over all the windings to hold the wire in position; but it is not necessary to attempt to impregnate them completely, unless the circuit must operate in very damp conditions. When both inner and outer coils are complete, the smaller one is pushed inside the larger one, and centrally located. It is then fastened in with wax; and the complete transformer is ready for use.

With the experience gained by building several small portable oscilloscopes using conventional methods of e.h.t. supply, the author can give an assurance that even for voltages of 1,000 the r.f. oscillator method is well worth the extra trouble, for the sake of the advantages gained. There is almost no difficulty in obtaining that oscilloscope ideal, which is often so difficult to realize—a perfectly focused, and uniformly illuminated straight trace across the screen.

Broadcast Receiver Design

Discussion on the Influence of Wartime Developments

At a meeting of the Radio Section of the Institution of Electrical Engineers on December 18th, 1950, R. B. Armstrong, B.Sc., A.M.I.E.E., opened a discussion on "Have Post-War Broadcast Receivers Taken Full Advantage of Wartime Development?"

Mr. Armstrong began by stating that, broadly speaking, receivers fell into three categories: (a) For home use in the entertainment field. (b) For industrial services, e.g., large traffic-carrying organizations. (c) For the Fighting Services.

Prior to the second world war, the very large market in category (a) had resulted in mass production of components and valves, the success of which had been judged by its ability to meet comparatively easy operational conditions at highly competitive prices. The design problem in the remaining two categories was how to ride on the back of this wave of mass production, while meeting much more stringent requirements.

The switch-over of the industry during the war to designs for Service use almost exclusively, radically changed this picture. The economic factor disappeared, except as a problem of availability of materials and manpower; the emphasis was on reliability and performance.

In considering how far the design of post-war broadcast receivers could or should be influenced by the industry's wartime experience, the following aspects of the question meriting discussion were suggested:

(1) What were, or are, "the advantages of wartime development"?

(2) Was there any positive evidence that the average listener in either (a) the home market, or (b) overseas, enjoyed happier service from post-war models than he did with pre-war designs?

(3) How far could the industry afford to employ any or all of the wartime "advantages" in a return to highly competitive markets? Alternatively, in view of the emphasis on the export market, how far could it afford to neglect them?

(4) Were the steps being taken towards standardization and rationalization adequate? To what extent could such steps be expected to bridge apparently wide diversities of requirements? Would the benefits of such steps bring about a sufficient reduction in cost to enable the most exacting specification to apply to Service and domestic designs alike?

In the discussion which followed the general opinion seemed to be that, so far as circuitry was concerned, television receivers had, to some extent, benefited from wartime developments, but that broadcast receiver designers had found little that could be usefully employed.

It was generally agreed, however, that broadcast receiver manufacturers had benefited by the development of new materials and their production in large quantities; e.g., insulating plastics (television cables), low-temperature-coefficient ceramic dielectrics (high-stability oscillator circuits) and magnetic alloys (loudspeaker permanent magnets).

The consequences of possible failure of Service equipment and the need for reliability of a high order were underlined, but one speaker thought that even in this context there was an upper limit to cost. If specifications were "written up too high" a prohibitive price might have to be paid in production delays and reduced output. In assessing the degree of reliability which should be provided in ordinary broadcast receivers, the balance of cost of service to the consumer, over, say, 10 years, was the true criterion. This included designing, production and servicing, and a lower overall figure might be achieved by allowing more for servicing and less for the initial costs of production.

The effects of currency inflation were held to be in some measure responsible for the failure to adopt many wartime developments in component design. This same factor had stripped sets of "gadgets," the effect of which in the years immediately prior to the war had been chiefly to increase the obsolescence rate. One speaker was sorry that push-button tuning had not survived in low-priced sets, since it greatly simplified tuning for the majority of listeners.

Increased use of bandspread tuning, the improvement of gain and frequency stability, and the provision of adequate tropical finishes in post-war sets were gaining prestige for British industry and should be maintained.

Little support was forthcoming for the idea of a system of component standardization which would satisfy the essentially divergent requirements of Service and broadcast receiver designers. Service receivers were designed for a specific use and to an exact specification. Broadcast receivers, on the other hand, were made to be sold, and had to be designed to the estimated requirements of listeners in all parts of the country.

All were agreed that receiver designers could be exonerated from responsibility for shortcomings in performance arising from economic difficulties; they had made the best possible use of the resources at present available, and in wartime had shown what they could achieve when given a freer hand.

Radio in the Jungle

Propagation through Dense Vegetation and Humid Atmosphere

By "PRONTO"

OPERATIONS in Malaya involve patrols of police and military going into dense jungle to form a firm base from which to operate for several weeks against bandits. Such patrols need communications to their headquarters outside the jungle for the two-way passage of information and to call for air supplies or air evacuation of casualties. Wireless is the only possible means of communication for forces which are several miles into thick jungle, but for it to be effective several problems have first to be overcome.

The jungle of Malaya is very dense indeed, so that very often the way must literally be cut step by step; it is also very humid and there is damp vegetation everywhere. Trees are extremely tall and generally close together, while the terrain is hilly. Such topographical conditions cause two major technical difficulties to hamper wireless communications. First, the high degree of ground-wave absorption and secondly, the considerable amount of atmospheric interference in the tropics. Let us consider the absorption effect first.

The humid atmosphere and damp equatorial vegetation of the jungle limits ground-wave communication to a few hundred yards when portable sets, radiating up to 5 watts on frequencies between 2 and 40 Mc/s, are used. The accompanying table shows results of experiments carried out to determine ground-wave ranges from a 3-watt transmitter using a 32-ft rod aerial. Ranges are given in miles.

Similar experiments, using a smaller set of 0.5-watt output, give an average signal-strength reduction to about one-eighth when the set is worked in jungle from open "lallang" grassland.

From the table it can be seen that the lower the frequency the greater is the ground-wave range, especially during day-time. Fig. 1 shows this effect within the normal military frequency range of 2-10 Mc/s.

The absorption effect is very much aggravated when v.h.f. sets are operated in Malaya. Even in rubber areas, let alone jungle, the range of the equipment in general use is limited to 300-400 yards. This is doubly unfortunate, as the Army has adopted several v.h.f. sets since the war to avoid the noisy and crowded h.f. band. However, the conclusion must be that jungle signalling should be on sky-wave, and hence that the v.h.f. set is unsuitable, despite the considerable advantage of a decrease in atmospheric noise on these frequencies.

It is also unfortunate that absorption causes the skip distance to be increased owing to a reduction of ground-wave range. In jungle, where ground-wave radiation is so poor, the skip distance of h.f. sets of up to 3 watts output may be as much as six miles. This problem only effects communication between two jungle patrols because in most cases the control set outside the jungle can be moved back to maintain a distance greater than the skip distance. In the case of two jungle patrols operating near together, lateral communication must invariably be through their control station.

The reduction of range at night is due to the high

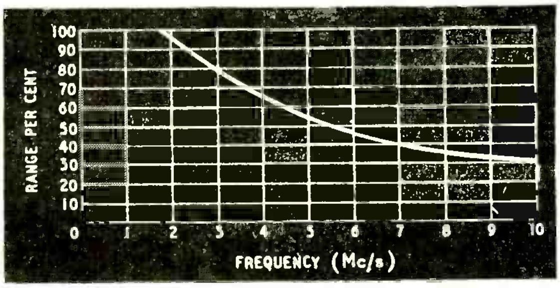
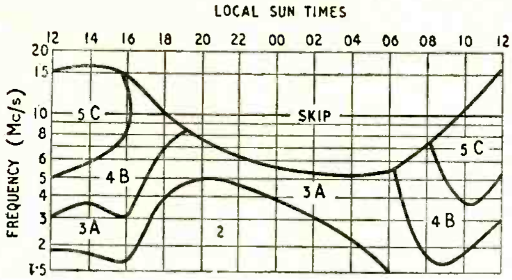


Fig. 1. Percentage ground-wave ranges obtained in the jungle at frequencies between 2 and 10 Mc/s.

Table of Ground-wave Ranges (in miles) Obtained in Malaya with a 3-watt Transmitter

FREQUENCY IN Mc/s	DAY				NIGHT			
	Telephony		Telegraphy		Telephony		Telegraphy	
	Jungle	Normal	Jungle	Normal	Jungle	Normal	Jungle	Normal
2	1.8	24	2.5	50	0.7	4	1.1	11
4	1.3	15	2.0	32	0.6	4	1.1	10
7	0.8	7	1.3	17	0.6	4	1.0	10
10	0.6	5	1.1	10	0.6	4	1.0	10



GRADE	0	1	2	3A	4B	5C	6D	7E
R/T	← NO RECEPTION →			← WORSE / BETTER →				
C.W.	NO RECEPTION	← WORSE / BETTER →						

Fig. 2. Typical Malayan sky-wave frequency chart.

level of atmospheric encountered in the tropics. A noise-level-against-time graph will vary with local storm conditions and with seasons, particularly at the monsoon periods. However, as a guide, it can be stated that smaller-powered sets will be blotted out and larger sets will be forced to change to telegraphy from 6 p.m. to 1 a.m. Then follows a period of two hours when the atmospheric is greatly reduced, until 3 a.m., when it increases to maximum again and then finally falls at about dawn. This in itself does not limit operations because the tactical requirement is not for continuous transmission, but rather for guaranteed communication twice a day—that is, when a patrol rests for the day and just before it marches on the following day. Even in the worst possible conditions this is possible at about 5 p.m. and just after dawn, while during the period between 1 a.m. and 3 a.m. wireless can often be used effectively.

The fact that telephony is not always possible makes command more difficult by restricting the "personal touch" to key-conversations, but it should be realized that jungle anti-bandit operations rely on silence for success, which frequently precludes the use of telephony.

Frequencies and Aerials

Bound up with efficient sky-wave communications is the selection of working frequencies; for this the Frequency Prediction Charts for Malaya are used. The difficulty is to select a frequency up to, but not above, the best working frequency. For this reason communication with low-powered sets in Malaya between 10 a.m. and 4 p.m. is difficult, since present available sets cannot follow the steep rise of the best working frequency. During the night 5 to 5.5 Mc/s should normally be used, and by day 8 to 10 Mc/s is the best range, whereas the best available set has an optimum frequency of 5.2 Mc/s. A typical Malayan sky-wave frequency chart covering distances of 0-200 miles is shown in Fig. 2.

It is best to select two frequencies, one for day and one for night working, the aerials being cut accordingly

It will be appreciated from the foregoing that aerials play an important part in jungle signalling Except for distances up to a quarter of a mile, vertical-rod aerials are of little use; similarly, although $\frac{1}{4}$-λ sloping aerials are quick to erect, they can only improve on the vertical rod by about $2\frac{1}{2}$ times. Therefore the best aerial has been found to be the sky-wave horizontal end-fed aerial, provided the range is over 6 or 7 miles.

Using present military h.f. sets, the aerial should be cut to $\frac{1}{4}$-λ or $\frac{1}{2}$-λ. Over 10 miles the most efficient aerial is undoubtedly the $\frac{1}{2}$-λ, but when using frequencies of about 5 Mc/s, the length needed would be 100 feet. The problem is then to find, or more likely to clear, an aerial site open to the sky, so that the aerial is three feet at least from any vegetation. Tall trees high overhead do not vitally affect radiation, but where possible they should be avoided; all vegetation below the aerial, however, must be cut away. For these reasons it is usually more practical to use a $\frac{1}{4}$-λ aerial, which even so may mean that the site takes at least two hours to clear.

Aerials should be roughly parallel and set about $\frac{1}{4}$-λ above the conducting stratum; the effect is then for the "water table" to act as a reflector and to boost the skyward portion of the signal. Better radiation can be obtained by placing a counterpoise earth directly below the aerial, or by erecting the aerial over a slight valley or over water. Improved communication also results if the first ten or twenty feet of the aerial is sloped, as this portion radiates most power, and if it were vertical the power would be absorbed as ground-wave.

Portability *versus* Power

Basically, the major problem of jungle wireless signalling is portability *versus* power, especially as a reserve set must invariably be carried. Because we need to get optimum efficiency from low-output sets the steps explained above have to be taken. If power were the only consideration the military set of 3- to 5-watt output would give good service for jungle patrols, but these sets are heavy, and they work off accumulators, so that a complete station, including charging facilities, needs at least nine men to carry it. This is normally prohibitive when jungle operations require every man to be fully armed and ready to fight at any moment. Also relevant is the fact that wireless equipment makes awkward individual loads, as well as being very fatiguing to carry.

The power supply of jungle sets raises a further difficulty. If accumulators are used, some form of charging must be provided, unless the very wasteful method of dropping charged batteries from the air is adopted. A form of pedal generator has been tried to save carrying petrol for charging engines, but it is itself heavy and much too tiring to operate after a difficult jungle march. Therefore one is forced to the conclusion that jungle patrol sets must work off dry batteries.

A final method of improving communication to jungle patrols is by the use of a higher-powered set outside the jungle, worked in conjunction with a separate sensitive receiver.

From the foregoing, it can be seen that the ideal jungle wireless set should work sky-wave on crystal-controlled frequencies of between 4 and 10 Mc/s. It should be extremely light to carry, simple to operate, with speech and Morse facilities; above all it must be robust and tropicalized. Small wonder that such a set has yet to be designed!

Manufacturers' Products

New Equipment and Accessories for Radio and Electronics

V.H.F. Transmitter

INTRODUCED by the Plessey Company, of Ilford, Essex, for radio-telephony communications is the type PT15 fixed-station v.h.f. transmitter, giving a power output of 50 watts. It covers the 118-132Mc/s band, and the actual working frequency is selected by inserting the appropriate crystal. Tuning the other stages is then done by means of maximum or minimum meter readings; this, however, is a simple operation as the number of tuning controls required has been reduced by the use of bandpass circuits. For servicing purposes a switched meter is provided for the r.f. stages, with test points to cover all the other sections. The complete equipment is made into three units; an r.f. unit, a modulator and control unit, and a power supply.

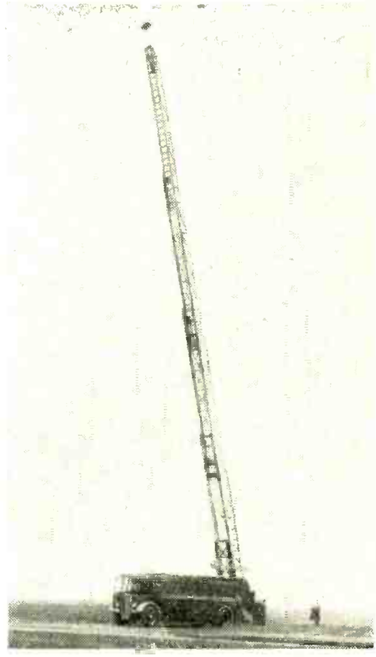
Television Receivers

A NEW television receiver has been introduced by the General Electric Company, of Magnet House, Kingsway, London, W.C.2. This is the BT5144, a table model fitted with a 12-in aluminized c.r.t., giving a black and white picture 10in x 7in. It has two controls only for normal operation; "brightness" and "volume/on-off," but subsidiary controls are accessible from the rear of the cabinet. Spot limiting and noise suppressing circuits are included to minimize the effects of interference.

From Valradio, Ltd., 57, Fortess Road, London, N.W.5, comes the announcement of a range of projection receivers for various mains supplies, the TVA for a.c., the TVDA for a.c./d.c., the TVD110 for 110V d.c. and the TVD50 for 50V d.c. The power supplies for the d.c. models are obtained from built-in vibrator units. Using the Mullard 2½-in projection tube, the sets give a picture 19in x 14¼in on a plastic screen.

O.B. Mobile Aerial

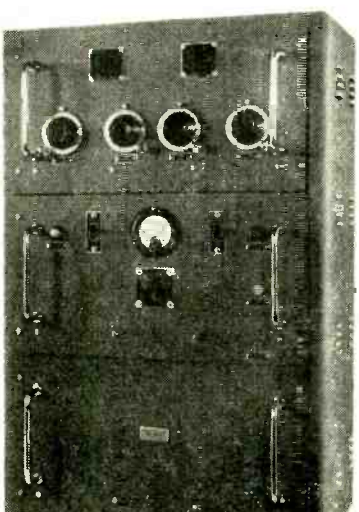
A MOBILE aerial unit has been designed for the B.B.C. for transmitting television outside broadcasts back to the studios. It consists of a van (in which the transmitter and generating set are housed) with a telescoping or fire-escape type of aerial mast mounted on top. The set of steel ladders forming this mast can be speedily erected to a height of 100ft, and the platform on top carrying the aerial can be swivelled and tilted by means of controls at ground level. The makers are Merryweather & Sons, of Greenwich High Road, London, S.E.10.



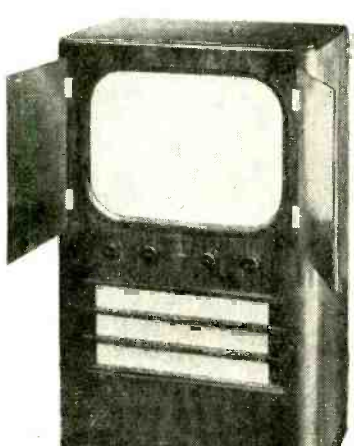
Merryweather mobile aerial unit for television outside broadcasts.

Long-playing Radiogram

THE new Philips radiogram, Model 603A, is characterized by its triple-speed record-changer,



Plessey type PT15 crystal-controlled v.h.f. transmitter.



Valradio projection television receiver, giving a picture size of 19in × 14¼in.

Philips radiogram with triple-speed record-changer for long-playing microgroove records.

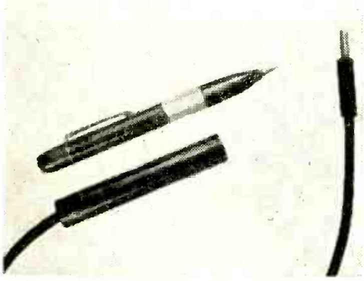
designed to take long-playing micro-groove records (33⅓ and 45 r.p.m.) and also the normal 78-r.p.m. type. Other features are the Philips "Featherweight" pick-up, which is much lighter than the normal type, and a sapphire needle which gives some 250 hours playing without having to be changed.

The radio side of the instrument is a 5-valve, all-wave superhet for use on a.c. mains, 100/250 volts. The wave ranges cover 715-2,000 metres; 185-580 metres and 16.5-50.5 metres. A built-in plate aerial is incorporated for reception of local stations, and sockets are also provided for external aerial and earth connections. The price is 69 guineas including P.T. Philips Electrical, Ltd., are at Century House, Shaftesbury Avenue, London, W.C.2.

Neon Testers

THE versatility of the neon lamp as a circuit and component tester is well exemplified by the range of "Neoflic" pocket testers introduced by Grafton, Kerston & Co., Ltd., 77, South Audley Street, London, W.1.

Different models cover the requirements of electrical wiring testing, checking car ignition systems and radio testing. In ordinary electrical work "live" and earthed lines are easily found, also whether the supply is a.c. or d.c., and, with the latter, polarity.



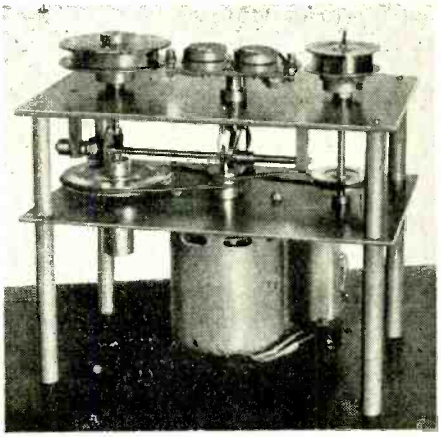
"Neoflic" pocket tester with the a.c. rectifier unit shown alongside.

It is also possible to use the device with a suitable d.c. voltage for checking the insulation resistance of capacitors. A small attachment containing a miniature rectifier can be plugged into one end of the tester. Using a.c. it is possible, with a little practice, to differentiate between high and low value of capacitance.

Prices range from 9s to 24s according to the functions they are required to perform.

Wire Recording Equipment

FOR magnetic recording experimenters who favour wire, Angel Scientific Products (Frank Mozer Radio, 5, Angel Parade, London, N.18) have introduced a range of units and components for use with stainless steel recording wire. The basic unit is a playing deck complete with record/playback and erase heads, incorporating automatic traverse mechanism for even laying of the wire in the take-up spool. The constant-speed driving motor has been chosen for minimum stray field and has an ample reserve of power. With one loaded spool giving ½-hour's playing time at 2 ft/sec, the price of the playing deck is £13 7s 6d, and extra spools are available at £1 each. Record/playback and erase heads are also available separately at £2 2s and £1 10s each respectively.



A.S.P. wire recorder unit.

Kits of parts for bias oscillator recording and playback amplifiers are available at £8 2s 6d and a power pack in kit form costs £3 10s. A circuit diagram of the amplifiers and power pack is available separately for 3s 6d.

CLUB NEWS

Bradford.—The meeting of the Bradford Amateur Radio Society on January 30th, when the subject will be "The Electron Microscope," will be held at the Bradford Technical College at 7.30. The second lecture in the series for junior members—on propagation and the construction of aerials—will be given at 7.30 on February 13th at the club headquarters, 66, Little Horton Lane, Bradford.

British Two-Call Club.—This club, which has a membership of 75, is exclusively for those transmitters who, having held a licence in this country, are now licensed overseas, or vice versa. Contact with members is maintained by the Club news letter "QTC" and on the air on 14 Mc/s, c.w., and 28 Mc/s, 'phone.

City of London Phonograph and Radio Society, which is mainly concerned with the electrical reproduction of recorded music, has recently produced crystal pick-ups for reproducing hill and dale recordings—both cylinder and disc—with "truly amazing results." Readers of *W.W.* interested in the reproduction of recordings—both ancient and modern—are invited to attend the meetings held on the first Tuesday of each month at 6.30 at 72, Wilson Street, London, E.C.2.

Derby.—The third and fourth lectures in the series on elementary radio, which is being given to members of the Derby and District Amateur Radio Society, will be delivered on January 31st and February 28th. At the meeting on February 14th the secretary will speak on harmonics and waveforms. Meetings are held in the Derby School of Arts and Crafts, Green Lane, Derby, at 7.30.

Hull.—The annual transmitting and receiving contest for Hull and East Riding amateurs, organized by the Hull Radio Group, will be held on February 17th and 18th. A copy of the rules is obtainable from J. R. Borrill, 321, Priory Road, Hull, Yorkshire.

Ilford.—The Ilford and District Radio Society, which meets at 8.0 on Thursdays at St. Alban's Church Hall, Albert Road, Ilford, includes in its winter programme talks on "Industrial Magnets" by A. J. Tyrrell of Mullards, "Problems of Valve Life Testing" by K. Brewer (Osram) and "Developments in Time Keeping and Frequency Measurements at U.H.F." by H. T. Stott, vice-president of the Society.

Luton.—A member of the Herts County Police will be talking at the meeting of the Luton and District Radio Society on January 29th. At the last meeting in February—26th—P. M. Clifford will deal with long-playing records. Meetings are held every Monday at 7.30 at the Surrey Street School, Luton.

South Shields Amateur Radio Club has been re-organized and meetings are now held each Friday at 8.0 in the Club Room, Trinity House, South Shields, which is open each evening. On Wednesdays an elementary class is conducted for junior members.

Speke.—The secretary of the Speke Radio and Television Society informs us that the club in is the process of being disbanded owing to the lack of support.

The names and addresses of the secretaries of the active clubs mentioned were given in the directory published in our last issue.

RANDOM RADIATIONS

By "DIALLIST"

Ships' Radar

My best thanks to the many readers who have written to me about their experiences with marine radar. Not a few, I am glad to say, tell me of captains and navigating officers who make a regular practice of running the radar set every now and then under conditions of good visibility and of comparing the PPI tube picture with what they can see ahead of and around the ship. There is no doubt that that is the best of all ways of developing confidence in the radar equipment and of learning how to make full use in thick weather of the information that it gives. Would that they all did it! It was a bit of a shock a while ago to listen to the evidence in a collision case in court. There was a thick fog, but the one ship of the two concerned which was equipped with radar had full warning of the other's approach a good half-hour before the crash occurred. The set was operated by "Sparks," who was able to supply a continuous stream of information about the range and bearing of the other ship. Neither captain nor navigator looked at the PPI screen, or made any plots of relative courses from the information given. And so the two vessels just came nearer and nearer to one another and finally collided — not in any narrow channel, but on the open sea.

Terminals

Many thanks, too, to those who have sent me either descriptions or samples of terminals in which wires are not ground or cut by the rotating point of a binding screw as it is turned down upon them. I am sorry to say that none of these terminals fulfils the ideal that I cherish, for all of them rely on contacts made by spring pressure. That kind of contact has two shortcomings: first of all, the spring exerts the same force, whatever the diameter of the wire—you cannot regulate the pressure to suit wires that are very fine or those that are very stout; secondly, springs tend to suffer in time from fatigue—in other words, the contact is liable to worsen as time goes on and you cannot tighten it up. No, what I want is a terminal with a positive screw-down contact made between two surfaces, neither of which rotates during the tightening process.

European Television Standards

We may take it that when new television systems are started on the Continent the standard adopted everywhere will be 625 lines, for, with the exception of the French and ourselves, representatives of all European countries have favoured that standard at all recent conferences and it is now accepted by the C.C.I.R. Experimental transmissions with 625 lines interlaced, 50 frames per second, and, I believe, vertical polarization have been going on in Holland and Denmark since the beginning of November, the Dutch using negative modulation and the Danes positive and negative on alternate days. It is reported that the transmitters in both countries are using a modulation bandwidth of 7 Mc/s; but this is hardly likely to be true, since the C.C.I.R has adopted a 4-Mc/s standard. Probably there has been confusion between modulation bandwidth and channel width: 7 Mc/s is the width allotted by the C.C.I.R. to each channel. Actually a 625-line, 50-frames system *needs* a modulation bandwidth of a bit over 7 Mc/s, if there is to be a proper balance between horizontal and vertical definition. So does the U.S.A. 525-line, 60-frames system — but it gets nothing of the kind. A modulation bandwidth of 4 Mc/s is talked about in the States; but most readers with practical television experience will know that it takes a pretty good receiver to do justice to the 3 Mc/s portion of the B.B.C.'s faithfully transmitted test patterns. I venture to doubt whether the more popular-priced American television sets (or televisers, as they call them) can handle properly a modulation bandwidth of more than 2.5-3 Mc/s.

Is it Wise?

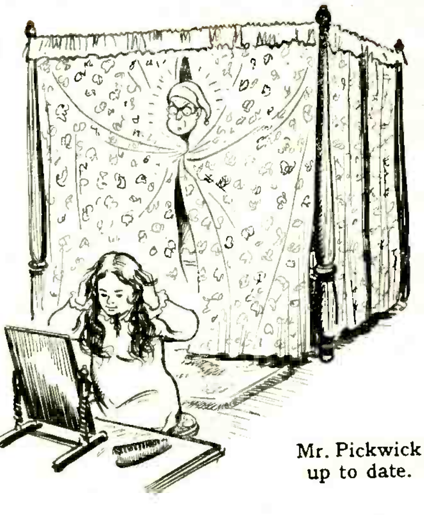
Whatever the transmitters may do, the television receiver within the reach of the ordinary man's purse in European countries is unlikely to be able to respond adequately to a wider band of modulation frequencies than this. It is not always realized that a greater number of scanning lines means a worse picture if either the transmitter or the receiver—or both—cannot handle the full appropriate range of modulation frequencies. I would be all for a 625-line European standard if transmitters were to use a 7-Mc/s modulation bandwidth and if I could see any likelihood of the man-in-the-street being able to afford the sort of receiver that is required to do justice to it. But it does seem rather like folly for Europe to plunge into a system in which (a) the modulation bandwidth of the transmitters is to be only 4/7 of that needed for a first-rate image and (b) only the more expensive receivers are likely to respond properly to more than about three-quarters of the already inadequate range of transmitted frequencies.

The Question of Cost

Television cannot make rapid headway anywhere unless satisfactory receivers can be bought at prices within the reach of a considerable proportion of the inhabitants. In thinking out this problem, it is no good expressing prices in pounds, francs, dollars, kroner or guilders. Wages and salaries and the purchasing power of money vary so much in different countries that the only sound basis nowadays for comparing prices is the number of hours, days or weeks of work that they represent to the average good citizen. I would say that in this country a reasonably good television receiver can be bought for about eight weeks' earnings of the average man. Prices are rather higher and wages much higher in America, where the cost of a receiver works out at under a month's average earnings. The pay of all classes is considerably lower in most European countries than it is here; in France, for example, the purchase of a 441-line receiver, whose price in francs is not much greater than that in pounds of a comparable British set, needs the earnings of about 16 weeks of the average man's work. I do not believe that television can become widely popular in any country unless the average man can buy an efficient and trustworthy receiver for the equivalent of eight weeks of his work at the very outside. And I do not see how that can come about quickly in Continental countries adopting 625 lines.

UNBIASED

By FREE GRID



Mr. Pickwick up to date.

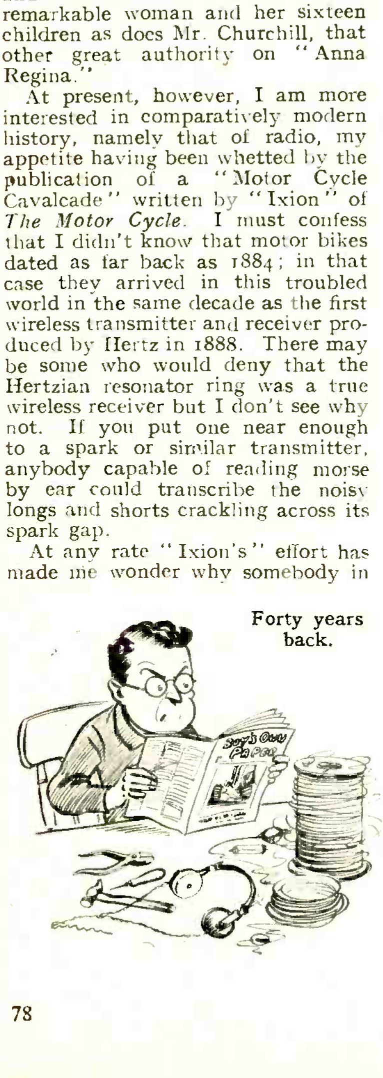
1888 *and All That*

HISTORY is a subject to which I have always devoted special attention since the time when, like the famous F. E. Smith, it floored me in an important examination. Like him I at once adopted the motto of *Nunquam Rursus* and, although so far it has not led me to the Woolsack as it did him, I never forget the words of Mr. Chamberlain "Time is on our side" and I feel that my chances are, at any rate, not less than those of this country seemed to be when he gave utterance to that famous sentence.

The particular question which floored me was "What was the original meaning of the saying 'Queen Anne's dead' and what feelings did it inspire in 1714?" Needless to say, since that unfortunate experience I have devoted much time to the study of Queen Anne and know almost as much about that remarkable woman and her sixteen children as does Mr. Churchill, that other great authority on "Anna Regina."

At present, however, I am more interested in comparatively modern history, namely that of radio, my appetite having been whetted by the publication of a "Motor Cycle Cavalcade" written by "Ixion" of *The Motor Cycle*. I must confess that I didn't know that motor bikes dated as far back as 1884; in that case they arrived in this troubled world in the same decade as the first wireless transmitter and receiver produced by Hertz in 1888. There may be some who would deny that the Hertzian resonator ring was a true wireless receiver but I don't see why not. If you put one near enough to a spark or similar transmitter, anybody capable of reading morse by ear could transcribe the noisy longs and shorts crackling across its spark gap.

At any rate "Ixion's" effort has made me wonder why somebody in the radio world cannot produce a "Cavalcade of Wireless." At the moment I am trying to find out when and in what journal appeared the first constructional details of a wireless set. I am afraid that we must rule out the forty-year-old *W.W.*, for although born in April, 1911, it held rather aloof from this sort of thing in its early days. The first constructional article of which I have any *personal* knowledge appeared in the *Boy's Own Paper*—still going strong—in the year of *W.W.'s* birth. It was a simple crystal set. But several years before 1911 at least one set was marketed—with a magnetic detector—by which watchmakers could check their wares by the Paris time signals, and I cannot help feeling that some journal must have published constructional details of a set long before the one I have mentioned.



Forty years back.

Cathode Cooking

SLOW starting from cold is a bugbear which afflicts motorists in the winter and users of indirectly heated cathode valves all the year round. Motorists can, however, now buy immersion heaters to stick in their radiators and can get a sort of ladies' hair dryer to blow hot air into their carburettors to vaporise the petrol quickly on a cold morning. For the I.D.H.C. valve user a very fat auxiliary heater of voracious "ampertite" has been suggested. But such a heater would itself take time to warm up. Personally I am going to try providing initial cathode heating by a "diathermic" cooker of prodigious power output. You know the kind of thing I mean; you can use it to bake a cake from the inside outwards or even to fry an inoffensive goldfish without heating the surrounding water or glass bowl.

Floreat Gippesvicensis

FORTUNATELY for listeners, the B.B.C. has not, so far, been dependent on sponsored programmes for its revenue. Those of you who have not had the same opportunities as I have had for listening to commercial programmes do not realize how much irritation can be caused by hearing constant reminders that "this programme comes to you by courtesy of Buggins' Personal Parasite Powder." Its constant repetition seems to have a psychological effect so that eventually the irritation ceases to be a metaphorical one and becomes physical, with the result that you hasten to the Drug store to get a packet of Buggins' P.P.P. which is, I suppose, exactly what the programme sponsor intended.

But the B.B.C.'s ban on advertising in any form can be carried to absurd limits. A striking instance of this occurred a few weeks ago when listeners were taken on a tour of the ancient town of Ipswich. One of the places which came into the programme was, very naturally, the hostelry where Mr. Pickwick, after getting into his curtained four-poster, was surprised, shocked and dismayed by the entry of a lady of uncertain years who showed by the preparations she made that she was obviously intending to get into it too. Now everybody who has read *Pickwick Papers* knows that Dickens laid the scene at the "Great White Horse" and everybody who goes to Ipswich sightseeing seeks out this ancient hostelry. But did the B.B.C. allow it to be mentioned by name? Not on your life; the other hotels in the town might complain of advertising.

Why, then, was the name of the Ipswich-born Cardinal Wolsey mentioned? Might not the other makers of gents underwear protest that the firm which uses the Cardinal's name and effigy as its trademark was getting an unfair advantage? Why, in fact, was the name of Ipswich itself mentioned? Might not other boroughs get jealous of the publicity given? Would it not have been better to have wrapped it up in its ancient name of *Gippesvicensis*? I was relieved, however, that the Bishop of St. Edmundsbury and Ipswich, who has his residence but not his ecclesiastical seat there, was completely ignored. Who knows what jealousy might have been aroused among the other Lords Spiritual.

LETTERS TO THE EDITOR

The Editor does not necessarily endorse the opinions expressed by his correspondents

F.M.: American Views

IN your October issue, under the heading, "VHF Mobile Communications," J. R. Brinkley comments on an article by me in the journal *Tele-Tech* (U.S.A.) about the progress of frequency modulation. Mr. Brinkley quotes the following statement from the article:

"In communications, the mobile services are still expanding rapidly. Here the use of f.m. is universal. No one would even attempt to sell a chief of police a.m. equipment."

The writer then proceeds to adverse criticism of the statement by citing statistics of the heavy preponderance of a.m. over f.m. equipment in use in similar services in the British Isles.

May I point out that my statement was, of course, addressed to the American reader and dealt with conditions in the United States? It would hardly be possible for me to comment on what is going on in other parts of the world. With respect to the remainder of Mr. Brinkley's letter, it might be noted that in the U.S. we have passed through a period similar to that cited in the letter, and have here settled commercial differences of opinion in the way they are invariably settled—by the verdict of industrial history.

As I am unfamiliar with the commercial situation in Britain, I forbear further reference. However, should Mr. Brinkley care to write the Editor of *Tele-Tech* about my article, the ensuing discussion will make clear why the choice in favour of f.m. was made in the U.S.

EDWIN H. ARMSTRONG.
Columbia University, U.S.A.

SEVERAL months ago you made a statement which upset me no little amount. The statement that upset me was to the effect that f.m. broadcasting was a waste of time and that in the U.S. time on f.m. stations could not even be given away.

First, let me qualify myself and my views. I am an engineer at KNOB, Long Beach, California. KNOB operates on a frequency of 103.1 megacycles with a power of 320 watts effective radiated power. The city we operate in is fairly large with a population of 250,000. In the same town are two standard a.m. stations: KFOX with 1kW, and KGER with 5kW.

KNOB went on the air in April of 1949, and we made the mistake, as did many other f.m. stations, that f.m. could be sold exclusively on fidelity. We got nowhere fast, and soon we decided that we would provide what people wanted and not what we thought they should want. We play popular records with the usual roll-off at about 8,000 cycles, we cover local sporting events between colleges and high schools, and we are present for most civic affairs which we at least tape record and rebroadcast. We also try to keep on a personal level with our listeners by having request record shows, and our studios are always full with people who have stopped in to chat a bit. We operate from 8 a.m. to 9 p.m. except for sporting events which may run later.

As a result we have more sponsored time at present than any other f.m.—only station in the Los Angeles area. We are also competing with seven television stations in this area.

Technically f.m. offers us several advantages. With essentially a 250-watt transmitter our day and night-time coverage is a radius of approximately 25 miles. In this radius we have no trouble with other stations interfering, nor do we have trouble with noise. As a comparison I shall use KGFJ, Los Angeles, which broadcasts on a frequency of 1,230 kc/s with a power of 250 watts night and day. At night their radius of reliable signal is down to about *six* miles. The majority of trouble, of course, is from distant stations sharing the same frequency.

As far as we can see at KNOB the answer to the congested frequency problem both here and in Central and South America and Europe is f.m. I see here that I should clarify my use of the term f.m. By f.m. I mean frequency modulation in the 88 to 108-Mc/s range. The high frequency, of course, reduces the congestion, and the f.m. provides quietness and fidelity. I hope the B.B.C.'s field test leads to the acceptance of f.m. in Europe.

CHARLES ANDERSON.
Clearwater, California, U.S.A.

E.M.F. or P.D.?

I MUST congratulate "Cathode Ray" on his ventilation of p.d./e.m.f. anomalies ("Voltage"—December, 1950, issue) and his wisdom in refraining from attempting generalized definitions.

Voltage is rather like beer, and is a variable mixture of e.m.f. (alcohol) and p.d. (water). If you apply the analogy to inductance at the moment of switching off current, or capacitance when fully charged, you get the right answer. Both pack quite a wallop, and it is right to infer that they are "over-proof" as far as e.m.f. is concerned.

HENRY MORGAN.

Hindhead.

Good Example

I SEE, on page 401 of the November *Wireless World*, reference is made to the substantial progress that is being achieved in the suppression of interference by spark ignition engines at the source for the betterment of television reception.

It may be worth recording in your journal that, for several months past, all the petrol-engined vehicles made by this Organization have been suppressed. The degree of suppression is that agreed by the Committee on the subject, which included Post Office representatives and also representatives of Joseph Lucas, Ltd., by whom we have been advised on the subject. In practical terms this means that most of our smaller cars are adequately suppressed with a single resistor in the main high-tension lead, but on some cars with lengthy high-tension leads the standard equipment includes individual sparking plug suppressors in addition and, in certain cases, resistors at either end of a lengthy main high-tension lead. This also applies to certain of the commercial vehicles.

Since the cost of this equipment to the manufacturer is very small, we have deemed it advisable to suppress in this way all vehicles we make, apart from those with diesel engines, including even tractors, and including, of course, the bulk of our production which is exported to markets thousands of miles from the nearest television transmitter. We felt, however, that the only thing to do was either to tackle the job properly or leave it alone, and we acted accordingly.

Unfortunately, owing to the extremely slow rate at which vehicles are reaching the home market, this change can hardly have any appreciable effect on television reception for a long time to come, but we hope, by demonstrating our disagreement with the stories that suppressors have a detrimental effect on engine performance, to encourage the retail motor trade to take similar action.

It goes without saying that all our own transport vehicles, whether commercial or private, have been suppressed in the same way for some time.

G. W. M. LUSH.

The Nuffield Organization.

Cowley, Oxford.

Resistor Colour Coding

UNLIKE your correspondent Peter D. Daw (November issue) I personally have had little difficulty in evaluating various brands of resistances from their colour coding and I have never known black to signify 1.

I would suggest that your correspondent made the following errors:

(1) The 33- and 330-Ω resistances. The 33-Ω was obviously wrongly coded—it does happen occasionally.

(2) 100,000Ω, black body, brown tip, yellow spot. In this case the sequence is brown, black, yellow—providing that the colours are in the form of stripes. With a black body a black ring would not show and is usually indicated by a gap between the other colours.

(3) 2,200Ω, black body, two red stripes. Here again there is probably a gap between the two red stripes and the sequence is red, black, red.

(4) 50,000Ω. Here your correspondent is confusing the old and new standard values. Green, black, orange is 50kΩ; green, brown, orange is 51kΩ—the standard value in the new system.

Incidentally, the numbers in the preferred values of resistances are as follows:—

10 11 12 13 15 16 18 20 22 24 27 30
33 36 39 43 47 51 56 62 68 75 82 91

R. REEVES.

Southall, Middlesex.

Television Colour Coding

I READ that it has been agreed to use a colour code for each frequency channel in the television scheme; a suggestion which is excellent in itself, but can it be explained why, after using a colour code for about twenty years, in which 1 is indicated by Brown, 2 by Red, etc., it should be necessary to adopt a new one to designate channels 1 to 5?

If it *must* be different, why adopt colours which we already identify with certain numbers to indicate some other numbers?

It seems to me to be utterly unreasonable that we must, if this new suggestion is adopted, learn that Yellow is not channel 4 but 1; that Red, Green and Dark Blue do not represent channels 2, 5 and 6 but 3, 4 and 5 respectively. Is it not possible to secure consistency among radio component manufacturers?

I suppose that this complaint is in some ways a follow-up of the letter from Peter D. Daw, on page 421 of the November issue, but I must confess to similar feelings of exasperation to that which he expresses in his letter on resistor coding.

L. A. C. HILL.

North Wembley, Middx.

Diodes for Drift Correction

ON page 350 of the October *Wireless World* it is suggested that the resistance of a diode with oxide-coated cathode should be 90 ohms when passing a current of 1 mA. In fact, one usually finds a resistance of several hundred ohms at this current, and the reason is that the formula $R_d = 0.09/I_d$ is not valid at a current of 1 mA in a small diode. (Valley and Wallman, as quoted in this context only suggest that it be applied for current less than 0.2 to 0.3mA.) The formula applies to the "retarding field" condition; i.e., it is based on the electrons reaching the anode on account of their velocities of emission and in spite of (rather than because of) whatever potential is applied to the anode; and it does not apply when the diode is working to the 3/2 law which we usually assume when neglecting the effect of emission velocities.

However, so long as $(\mu+1)R_d$ is not too large compared with $R_a + r_a$, the exact value of R_d does not seem important.

D. A. BELL.

Birmingham University.

Electrical Dangers

I WAS interested in Diallist's examples (p. 272, July) of the many dangers needlessly let loose on the public by "dabblers." My seven-year-old daughter was nearly killed by a more culpable example of such work than those quoted. Even so I am inclined to blame "the fruits of long experience and of patient, disinterested work" (a) for standardizing the supply to the public at a pressure of 230 volts, and (b) for deliberately altering the spacing of pins in 3-pin plugs as compared with 2-pin.

As to (a), the distribution could still have been 400 volts 3-phase, but by using a transformer for every house 110-volt lighting circuits (C.T. earthed) would be almost foolproof in addition to giving improved life and optical characteristics from filament lamps.

As to (b), the 3-pin socket would have automatically replaced the 2-pin with neither inconvenience nor opposition if the same spacing had been adopted. As things are, so very many appliances have standard

2-pin plugs that wherever possible their owners fight shy of 3-pin sockets. And if a 3-pin socket, correctly installed and earthed, etc., is the only point available, does it necessarily prevent the consumer from plugging in a non-earthed appliance or indeed a twin-wired one? Not on your life. He either bends the pins of his plug, uses one of the types which are guaranteed to make a contact (of sorts) with either socket, or takes the 2-pin plug off and pushes the wires in, taking little care to protect them.

I am not convinced that this earthing craze is altogether desirable, particularly as no one seems to care (least of all the factory inspector) whether the earth wire is really doing its stuff on both sides of the connection. Particularly do I object to earthing the frames of electric fires as anyone, including children and pets, may touch the element when switched off whilst contacting the frame.

In any case, few dabblers are quite as bad as certain householders who call themselves handymen, and, as no regulations can eliminate the latter, I blame the powers-that-be for giving them fire to play with.

HARRY CRAMPIN.
Grimsby, Lincs.

Pickup Design

SINCE my last letter to you on this subject I fear that the position has become somwhat confused and I would like you to allow me a little of your valuable space to comment on certain points.

In my letter published in your June, 1950 issue, I described the relationship between coil mass, size, velocity and point impedance, and from the considerations I gave it was clear that the number of turns on a coil of a given size and mass, working at a defined velocity would have no effect on the signal/hum ratio. At the time I was under the impression that a number of other conclusions would be easily drawn from my outline of the facts, but I regret to notice that no correspondent has given any indication of having really understood what I wrote at all, and I will therefore translate it into more practical terms.

Signal/hum improves at the rate of $<\sqrt{\text{increase in coil mass}}$ if velocity of conductor is maintained constant.

Point impedance increases at the rate of the increase in coil mass provided velocity of conductor is maintained constant.

∴ Signal/hum improves at the rate of $<\sqrt{\text{increase in point impedance}}$ when such increase is due to increase in coil mass only.

Signal/hum improves proportionately to increase in coil velocity provided all other factors are maintained.

Point impedance increases proportionately to coil velocity provided all other factors are maintained.

∴ Signal/hum improves proportionately to increase in point impedance when such increase is due to coil velocity only.

General conclusion.—The optimum signal/hum ratio in any coil system *reflecting a given point impedance* is obtained by a system of minimum mass operating at maximum velocity.

This is one aspect of what I have called the principle of distributed mass.

Let us now look at another aspect of this principle: a small coil of rectangular shape has N turns, mass M milligrams and conductor length per turn L mm. We will reduce the turns to ½N and maintain M by increasing L by increasing the length of the coil axis which is the axis of rotation. The reflected point impedance is identical in both examples but the signal/hum ratio of the latter system is better than the former by rather less than $\sqrt{2}$. Here again in a minor form we see the importance of the principle of distributed mass.

Now before relating these conclusions to practical examples I would like to define some basic differences between a moving coil system and a ribbon system. A moving coil is a system rigid in itself having inherent mechanical characteristics by virtue of its shape, mass and stiffness. Its performance is improved by obtaining the maximum stiffness for a given mass, which implies the *greatest possible concentration of mass*. Being a rigid structure it can operate only with the aid of some external suspension. A ribbon is a system in which the mass is distributed as much as possible in two dimensions; which, by itself, has, relatively speaking, no stiffness and no particular mechanical characteristic, these depending almost entirely on the nature and tension of its suspension. It operates by the flexing of the moving conductor.

It is therefore inherent in the systems concerned that the moving coil is a system utilizing the principle of the greatest possible concentration of mass, and the ribbon system operates by using the principle of distributed mass. It is therefore incontestably conclusive that the moving coil has the worst possible signal/hum ratio and the ribbon the best possible signal/hum ratio. In practice, the signal/hum ratio of the moving coil is so poor that it is completely unworkable in designs having very low reflected point impedances and in such designs the ribbon is the only possible choice.

So that we may fully appreciate this point in practice, we will take examples of ribbon and moving coil designs having reflected point impedance factors of ½.

Ribbon design. Mass = ½ milligram. Velocity factor 1. Reflected point impedance factor ½.

Moving-coil design. Mass = 48 milligrams. Velocity factor 1/96. Reflected point impedance factor ½.

Improvement in signal/hum ratio of ribbon over moving coil due to velocity factor = 96.

Improvement in signal/hum ratio of moving coil over ribbon due to greater mass = $<\sqrt{96}$.

Overall improvement of ribbon over moving coil = $>\sqrt{96} = >20$ db.

This, it should be noted, is only part of the superiority of the ribbon over the moving coil; other contributory factors would give a total superiority of about 40 db. Another point to bear in mind is that a ribbon design in which the moving conductor has a reflected mass at the point of ½ milligram is very much a practical proposition and therefore the advantages demonstrated are actual realities. On the other hand, a moving-coil system having such a low reflected mass at the point has never so far been made and it is unlikely that it ever will be made until some material with the specific gravity of hydrogen and the mechanical strength of steel is invented. We may therefore claim that the ribbon permits a design that is unique in the low point impedance possible, and that such a design is usable only because of the great inherent superiority of the ribbon principle of distributed mass.

And we may also state that the moving-coil principle can be employed satisfactorily only in designs where the mass and reflected point impedance are relatively high and where the comparatively poor signal/hum ratio of the moving-coil system can be tolerated. We must also be quite clear in our minds that signal/hum ratio, if it is to mean anything at all, must be related to the reflected impedance at the point of the moving system.

I assume that it will be understood that there is a limit to the application of the principles I have mentioned. For instance, a ribbon design of as much as 50 milligrams or more mass would be either too extended in size or too concentrated —and therefore too stiff—to be satisfactory. There is therefore a top limit to the satisfactory use of the ribbon principle as well as a bottom limit to the practicable employment of the moving-coil system.

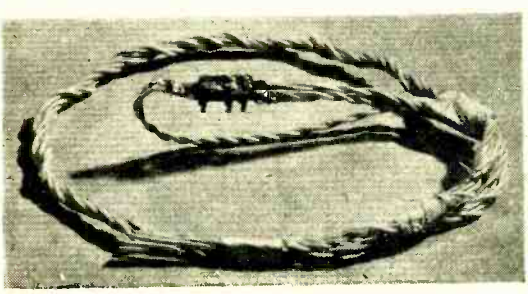
As I have already taken up most of the space that can probably be allotted to me I will comment only very briefly on one or two points made by a previous correspondent.

In the practical test described in your July, 1950, issue by H. J. Leak, as the two pickups concerned had entirely different effective point impedance factors, the comparison was invalid. Moreover, about 95% of the hum attributed to the ribbon pickup would be due to the coupling transformer, so that the experiment failed owing to the complete neglect to maintain equal conditions and the failure to attribute the results so obtained to the correct component. Furthermore, the positioning of the transformer relative to two sources of hum was carried out incorrectly and effectively prevented their correct location. I have gone into this elsewhere* and will not repeat myself here.

As regards the remarks and drawing by Mr. Leak of a ribbon pickup; so far as I can tell the pickup described is not a standard design and I would hazard a guess that it is what we call a P/R/1 conversion, the movement being made during a period when the design was ahead of the press tools. The signal/hum ratio would be about 6 db down on the present ribbon cartridge, the relevant details of which are given with the accompanying photograph. I apologize for referring in these pages to a commercial design, but I know that it will be very widely appreciated that I have been forced to correct certain inaccurate data and descriptions.

J. H. BRIERLEY.

J. H. Brierley (Gramophones and Recordings), Ltd., Liverpool.



Ribbon cartridge (Type JB/P/R/3). The ribbon is centre-tapped to maintain a balanced input. Total mass of moving parts (excluding point) less than ¾ milligram. Resistance of ribbon = ⅛ ohm. Resistance of leads = 1/40 ohm. Loss in signal/hum due to leads not more than 1 db.

* Booklet, "Reproduction of Records".